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A dynamic approach to cost finding for railways,

with special reference to the freight traffic of the Swedish State Railways,

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As with every other production, the railway's production of haulage services demands contributions of different means of production (goods and services). The railway's production requires therefore the existence partly of certain permanent structures, such as tracks, station premises, workshops, etc.; partly of certain rolling stock, that is to say locomotives, cars, etc.; partly of certain staff for employment on stations and trains. These means of production requisite for production can be classified in the three following main groups :

1. *Operating staff* i.e. employees for staffing the various traffic establishments belonging to the railway, for the dispatching of passenger and goods traffic, for the assembling of trains, etc., as well as for crews on trains and for the safe conduct of trains on the track.

2. *Operating material* i.e. such articles of consumption of various kinds which are used by the employees in the carrying out of their tasks or which are necessary for the running of the trains.

3. *Permanent structures and rolling stock.* As permanent structures are considered the track with all its appurtenances, stations, engine-houses and other buildings, etc. The rolling stock includes locomotives and cars of various kinds.

In order to be able to have these different means of production at one's disposal, the railway company must make payment with money. The starting and carrying out of the process of production entails therefore a series of disbursements, hereafter referred to as *expenses*, as it has not been considered necessary to distinguish here between the point of time, when the liabilities for payment arise and when the payment is made. Similarly, the railway company receives, when payment for the haulage services sold is made, a series of payments or *receipts*.

These expenses and receipts are recorded currently in the company's accounts together with other economic transactions and also raw materials and articles of consumption spent, work and haulage services performed as shown in the operation statistics. For practical reasons the recorded events are summed up periodically in the accounts and statistics, usually once a year (bookkeeping year).

The series of expenses are of quite dif-

ferent types for the three main groups of means of production given above.

Payment to the permanent employees of the company i.e. permanent, extra permanent and aspirant staff as well as certain other employees with permanent employment, is made in the form of monthly salary during their time of employment. There is in addition for permanent and extra permanent employees, on leaving their employment at pension age, an old-age pension for the remaining part of the lifetime of the person concerned. Payment is made per day to *temporary employees* for the time that the person concerned is in the employment of the company.

These series of expenses, concerning the payment of the staff, form thus *continual* series with certain amounts per month or day, which at least in the long run are quite closely allied with the size of the production during different periods of time.

In the question of *operating material* it is also true that these series of expenses are very continuous in time. The series also are closely allied with the size of the production during the period of time concerned.

As regards the *permanent structures* and the *rolling stock*, the series of expenses have partly another character. Here one has *partly* a number of points with perhaps 40-100 years' interval with large expenses for the providing of the permanent structures and the rolling stock; *partly* a rather continuous series of disbursements for the maintenance of these structures or this rolling stock during the time it is in use. As a rule it is true for these means of production that their series of disbursements are less closely related to the size of the production than either of the other two main groups.

With regard to their connection with the production over a certain period of time, for example one year, the expenses during this period may be divided as follows :

1. Expenses, connected only with the *present* production. This is the case with expenses for operating material and disbursements for wages to temporary employees.

2. Expenses, connected *both* with *present* and *future* production. Into this category fall all expenses for providing permanent structures and rolling stock, and as a rule disbursements for wages to the permanent staff of the company.

3. Expenses, connected only with *future* production, occurring for example, in such cases, where structures are adapted in advance to fulfil the greater needs of the future.

4. Expenses, connected only with *previous* production, consisting for example of pension payments to pensioned employees or expenses for posponed or neglected maintenance of structures or rolling stock.

The series of expenses required for the carrying out of a certain production is called (real) investment. As the investment in our case is primarily occasioned by the series of receipts, which can be expected on the sale of the haulage services, it is necessary for the complete characterization of the investment that both the size and the time factor in the distribution of the expenses and receipts series are given.

I. THE RAILWAY COMPANY'S TARIFF AND PRODUCTION CALCULATIONS.

Railway production with its means of production of a very permanent character, necessitates the planning of produc-

tion and investment for a longer period of time. What is primarily required here is an understanding for the expected development of the demand for the railway's haulage services under varying conditions. On this basis, plans can be made as to the best way of handling the potential haulage demands, as well as regarding employment policy and the pursuance of a far-sighted policy as regards the procuration of structures and rolling stock. Further, these plans allow an estimation to be made of the size and time factor of the potential future expenses and receipts of the undertaking. See part II : « Planning and calculation of expenses for a certain alternative » for a more detailed description of this planning.

The series of expenses and receipts according to the planning, consisting of expenses and receipts, falling due at various points of time in the future, are not altogether comparable. In order to be comparable they must be assigned to the same period of time, that is to say, the capital value must be estimated at a certain point of time, usually that when the calculation is made, of all future expenses and receipts. The undertaking's (subjective) *capital value* at the point of time of the calculation is obtained in the usual way as the sum of the values of all future net receipts, calculated as the difference between receipts and expenses, and discounted at the rate of interest applicable to the undertaking.

If the (subjective) capital value of the undertaking at the time of calculation t is symbolized by C_t, the rate of interest by i and the receipts and expenses over the period k by R_k respectively E_k and if the undertaking is assumed to be (or the planning to include) n periods, the following formula is obtained for estimation of the capital value previously mentioned :

$$C_t = \sum_{k=1}^{n} \frac{R_k - E_k}{(1 + i)^k}$$

It should specially be pointed out here that the undertaking's capital value as well as the expense and receipt series are determined with direct reference to a certain production plan for the future. If alternative plans for the future exist at the point of time of the calculation, which is usually the case, as many (subjective) capital values for the undertaking can be estimated as there are alternative plans. During the course of development from the point of time of the estimation, a successive revision of the various plans is generally made with regard to the development effected, and the revised capital value can therefore be calculated at these future points of time.

The calculations required by the railway for its price and production and investment policy, are intended to gauge what changes a certain potential measure may be expected to entail as regards the size and the time factor in the company's future expenses and receipts series, as compared with what would have been the case, if the measure had not been taken. On the ground of these particulars it can then be calculated what effect the measure in question can be expected to have on the capital value of the company, at the point of time of the estimation and if the measure in question can be considered from the viewpoint of business economy as « profitable » or not. These calculations shall therefore hereafter be called *profit calculations*. It must be specially pointed out here, that every profit calculation concerns the *future*. It is only the anticipated future expenses and receipts that are included in the calculation. Events before the point of time of

the calculation can only indirectly be relevant to the calculation, namely to the extent that they influence the company's future expectations and its appraisal of the future. The past receipts as well as the past expenses for the procuring of structures still in use, or the value of these structures in the accounts at the calculation moment are of no significance for the calculation in question. On the other hand are the point of time and the size of the future expenses for the maintenance of the permanent structures relevant for the calculation. It can be said as a rule that the particulars recorded in the accounts regarding the company's production and turnover, referring to past events, cannot be employed in the profit calculations, which instead are based on anticipated future expenses and receipts.

A never-ceasing need exists for a rational formation of price and production policy in the railway undertaking for the establishment of such profit calculations, which can provide answers as to the question of the *business economic consequences* to the company of the different proposed measures. The final decision as to these measures will, however, not always be made on the grounds of the economic consequences for the company, but regard to the economic consequences for the community must play a part in the decision. These decisions as to policy are facilitated to a very great extent, if the economic consequences to the company of the alternatives in question have been made clear in advance.

The question, which form the point of view of the economic policy of the railway, are probably the most important and concerning which profit calculations are primarily required, are comprised in the following :

1. How does a certain increase in traffic, occasioned by the lowering of tariffs or by other reasons, affect the company's expense and receipt series ?

It is then necessary to investigate how both these series are shaped, both with and without the increase in traffic in question, and the capital values for both these alternatives must be calculated.

2. How does a certain decrease in traffic, occasioned by the raising of tariffs or by other causes, affect the company's expense and receipt series ?

In analogy with case 1, the capital values for both the alternatives with the decrease in traffic and without the decrease in traffic must be calculated.

3. What effect does a change-over to another method of production, for example the electrification of a section of the line with steam-power or the transfer of less than carloads (L.C.L.) haulage from local trains to rail buses, have on the company's expense and receipt series and thereby on the company's capital value at the point of time of the calculation ?

In addition to the cases mentioned, the railway naturally requires profit calculations for a number of other contingencies as well, which can arise in the course of operation. The question, for example, can arise as to how the production shall be divided as to time; when the means of production shall be discarded; if traffic on a certain section of the line shall be discountinued wholly or partially; if certain trains shall be discontinued, etc.

Fundamentally it can be said that all these profit calculations are *total* calculations, i.e. when calculations are made for a certain alternative, due regard must be taken to the effect that this alternative will have on *all* the future expense and receipt series of the company. On account of this connection, partly in time

and partly in space, found in the railway production between the various part processes, a change in a certain part process can entail a change not only in the expense and/or receipt series belonging to this part process but also in the expense and/or receipt series belonging to other part processes.

A. Additional receipts and additional expenses as well as capital values of the same.

It has previously been pointed out that when determining the profitableness of two production alternatives, between which one has to choose, for example the alternative to grant a decrease in tariff or not and thereby obtain respectively not obtain a certain increase in traffic, one should compare the future developments of the company's expense and receipt series in both cases. As it is the *difference* between the two alternatives, which is relevant for the calculation, one need naturally not include in the calculation such items of expenses or receipts which are identical in size and time in both alternatives. What is sought, is therefore the additional receipts and additional expenses for the measure planned (alternative under examination) as compared to the alternative chosen for comparison. When the additional receipts and the additional expenses have been determined, one can by discounting up to the calculation moment estimate the additional receipts' and the additional expenses' combined value at that point of time. This capital value shall hereafter be referred to as *capital value of the additional receipts* respectively *capital value of the additional expenses* for the *production alternative concerned.* The difference between the capital value of the additional receipts and the capital value of the additional expenses can be called the *additional capital value* of the production alternative concerned. Setting out from designations given previously and introducing the index of (1) for quantities concerning the alternative under examination and (0) for the alternative chosen for comparison, the additional capital value of the alternative under examination $C_t^{(1:0)}$ is obtained in accordance with the following formula :

$$C_t^{(1:0)} = C_t^{(1)} - C_t^{(0)}$$

$$= \sum_{k=1}^{n} \frac{R_k^{(1)} - E_k^{(1)}}{(1+i)^k} - \sum_{k=1}^{n} \frac{R_k^{(0)} - E_k^{(0)}}{(1+i)^k}$$

The capital value of the additional receipts $({}^rC_t^{(1:0)})$ respectively the capital value of the additional expenses $({}^eC_t^{(1:0)})$ for the alternative chosen for comparison can be calculated according to the following formula :

$${}^rC_t^{(1:0)} = \sum_{k=1}^{n} \frac{R_k^{(1)} - R_k^{(0)}}{(1+i)^k} \text{ respectively}$$

$${}^eC_t^{(1:0)} = \sum_{k=1}^{n} \frac{E_k^{(1)} - E_k^{(0)}}{(1+i)^k}$$

As the capital values of the additional receipts and the additional expenses for the production alternative concerned form in time a joint receipt respectively expense *for the entire series of years with which the production alternatives are concerned,* the additional receipts respectively additional expenses *for a single year* can only consist of a part of this receipt respectively expense. How this joint receipt respectively expense shall be distributed over the different years is however more a question of suitability. Usually one considers it reasonable to credit respectively burden the different years with similar shares and the year's

additional receipts (R^*) respectively year's additional expenses (E^*) for the production alternative in question will then be the same as the annuity for the capital value of the additional receipts respectively additional expenses at the point of time of the calculation, estimated with regard to the number of years which the production alternative is expected to exist. Thus

$$R* = {}^{r}C^{(1:0)} \cdot \frac{i(1 + i)^n}{(1 + i)^n - 1} \text{ respectively}$$

$$E* = {}^{e}C^{(1:0)} \cdot \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

The preceding discussion concerning additional receipts and additional expenses has primarily arisen from circumstances with an increase of traffic. If the production alternative on the other hand concerns a decrease in traffic, the capital value of the additional receipts and the capital value of the additional expenses should as a rule be negative. Instead of speaking of negative capital values it would seem more suitable even in these cases to calculate the quantities positively and to speak of the *capital value of the decreased receipts* respectively the *capital value of the decreased expenses*.

B. Additional expenses for working staff and material.

When it is a question of the current consumption of the means of production for a certain new traffic (additional traffic), there is no difficulty in calculating the additional expenses, as far as the means of production are concerned, which partly are used entirely for this additional traffic, partly can be said to be used entirely on account of conditions connected with the year's traffic concerned. This can be said to be the case both concerning temporary working staff and operating material. The additional expenses for a certain year will then be the same as the disbursement for wages to the temporary staff respectively the disbursements for the obtaining or re-obtaining of the operating material used during the year.

In certain cases, the current consumption of the means of production for a certain year depends on other conditions than those of that year. Thus the disbursements for wages to the permanent employees can vary with the length of service of the employees within the salary-grade concerned and with the salary-grading of those concerned. Similarly, the railway's disbursements per annum for the maintenance of cars can vary with their age; the disbursement for the maintenance of the track can vary for different years on account of climatic conditions or because certain forms of maintenance work are not carried out every year. In such case it would be advisable as far as possible to endeavour to equalize the variations in disbursements of the different years and instead to calculate with the average expense for longer periods of time.

As far as the permanent working staff is concerned, it would be advisable, if the varying disbursements for salaries depending on the age of the employees and advancement in service as well as the disbursements for pensions arising from the pensioning of employees, should be equalized in the manner already described, so that for the entire « lifetime » of the employees with the railway company a constant yearly cost is obtained for disposal of the staff. The maintenance expenses varying with the age of the rolling stock should also be equalized in a similar way, so that for the entire life-

time of the rolling stock one gets a constant yearly cost for maintenance. The annuity calculations has then a definite aim, namely the independency of the expenses for the employees respectively the rolling stock for a certain year, irrespective of new employees respectively material are being employed. On the other hand the annuity calculation has of course no connection with the question of fluctuations in the wage-level itself for the employees respectively the price-level for the maintenance. This question must be kept quite apart from the above. The object of the annuity calculation will therefore be to determine the annuity of the expenses for the employees respectively for the maintenance at a constant wage- respectively price-level, i.e. it is assumed that the estimated wage- respectively price-level for the year will be in force for the entire length of life of the employees respectively material and that the expenses for wages respectively maintenance will vary with the employees' respectively material's age according to the assumption serving as a basis for the annuity calculation. Thus the annuity expenses for the year in question must be adjusted upwards or downwards corresponding to the extent the wage- respectively price-level during a certain year deviates upwards or downwards from the assumed wage- or price-level.

C. Additional expenses for the renewal of permanent structures and rolling-stock.

The expenses for the renewal of the permanent structures and the rolling stock occur at different times in the future. The comparison between the two alternatives of the profit calculation is intended therefore, as has been pointed out previously, as a comparison between two series of expenses. The capital value of the additional expenses for the production alternative examined is obtained as the difference between the capital value of the additional expenses at the point of time of the calculation for both series of expenses. This capital value, as previously mentioned, consists of the additional expenses for the capital object's employment during the entire series of years, that the production alternative in question is in existence, and therefore the additional expenses for a single year can only be a part of the same. If one considers — as will usually prove to be most suitable — that the various years should be burdened alike, the annual expense will be the same as the annuity for the capital value of the additional expenses, calculated with regard to the number of years that the production is expected to continue.

D. Additional and decreased expenses per item.

If the variation of only one type of transport is considered, for example less than carloads traffic (LCL) from A to B, and the additional expenses respectively decreased expenses relating to the said variation is divided with a figure of measurement for the variation in question, for example the « ton/km. » figure, the *additional expenses* respectively *decreased expenses per item* (per « ton/km. ») are obtained. Additional respectively decreased expenses per item for a comparatively small variation in traffic are called *marginal costs* (« upward » and « downward » respectively).

The size of the additional or decreased expenses in a certain case depends on the following circumstances :

1. The utilization of capacity, from which the traffic variation takes place.

2. The direction of the traffic variation in question (increase or decrease of the number of haulage services).

3. The size of the traffic variation in question.

4. The length of the period of time, which the traffic variation is presumed to cover.

5. The length of the period of time, during which it is possible to take measures with regard to an expected traffic variation.

The additional expense per item, which arises with an increase in traffic, can generally be said to become greater than the decreased expense per item with a corresponding decrease in traffic. As a rule it can also be said concerning expenses per item, that the more completely the capacity is utilized, through which an increase of traffic takes place, the greater the traffic variations are, the shorter the period of time the increase in traffic lasts, and the shorter the period of preparation for the carrying out of the increase in traffic, the greater will be the additional expenses per item.

A certain increase for example of LCL-goods traffic can perhaps be handled without employing an increased number of cars or employees, but a greater increase in the volume of traffic can demand an increased number of cars, employees and, in the event of the increase being very great, even an increased number of locomotives, increased storage space, etc. The additional expenses per item will, in the latter case, of course be greater than in the former.

As regards the influence of the capacity utilization in the initial position on the extent of the additional expenses, it can be said as a rule that if the increase occurs from already fully employed capacity, this can demand an otherwise not requisite increase in the number of locomotives, cars, etc. The additional expenses in this case, will be higher than if the capacity had been less well utilized in the initial position.

The length of the period of time, which the traffic variation is expected to cover, has a similar influence on the extent of the additional costs. Thus the additional costs per item should be less with an increase in traffic, which is estimated to last a long time, than if it is estimated to last only a short time. A short increase in traffic can be met by more concentrated employment of the rolling stock, even if this should entail a certain increase in the number of employees required and the cars' running without loads; a similar increase in traffic over a longer period of time should, on the other hand, often be met more advantageously by procuring more cars and eventually enlarging warehousing space, whereby running without loads and the demand for more employees can be decreased.

As regards the effect on the size of the increased expenses of the period of time, during which the preparations for the handling of the increase in traffic can be made, it can be said as a rule, that the longer the period of time available for making preparations, the more advantageously the increase in traffic can be met and the lower will be the additional expenses per item.

II. PLANNING AND CALCULATION OF EXPENSES FOR A CERTAIN ALTERNATIVE.

In the calculation of expenses for a future traffic situation defined in a certain way, it is necessary as the first step in the planning to see how the haulage in this situation should be handled by

means of the participation of different means of production, hereafter termed *operational planning.* The size, composition and time distribution of the haulage order in the traffic situation concerned constitute the basic factors for the operational planning. The result of the planning is termed as a whole the *operational scheme,* which is divided into a number of part schemes which are dealt with subsequently. Other factors in the calculation are formed by the definition, obtained on the basis of the operational scheme, of certain measuring numbers applicable for the performances included in the operation, here termed *operational quantities.* On the basis of the operational scheme and the operational quantities, arising from the same, and with the employment of the particulars, which can be obtained from the accounts and existing costs and operational statistics, the various central and regional administrative organizations of the railway then make a calculation of the expenses in the traffic situation concerned.

A. Operational planning.

Operational planning is the activity, which is carried out by different administrative organizations of the railway with the object of co-ordinating the necessary contributions of the different means of production for the handling of the haulage order. This activity results in the setting up of certain practical norms for action for the subordinate officials as regards the choice of transport routes, cars, etc., for the conveyance of the goods from one station to another. These norms for action are termed in practical operation route instructions, freight haulage instructions, service time-table respectively local time-table.

When calculating expenses it is essential to have hypothetic operational planning of a similar type for one or more traffic situations. The hypothetic norms for action, which will be the result of this operational planning, are here termed *route scheme, car scheme, train scheme* and *locomotive scheme.* These schemes have the following contents :

1) *Route scheme,* that is to say the determining of the transport routes, which for the respective station relations should come into use with the completion of the haulage order.

2) *Car scheme,* that is to say the determining of the number of cars of different types which should come into use for the different station relations.

3) *Train scheme,* that is to say the determining of how the various cars should be combined to form trains as well as how the trains should be driven and disposed.

4) *Locomotive scheme,* that it to say the determining of the types of locomotives, which should be used for the hauling of the special trains and for shunting.

In order to make the contents of the different schemes clearer, the following should be noted.

The *route scheme* is necessary because in many cases a choice between alternative haulage routes must be made.

As a basis for the choice of route there are certain operational economic considerations which briefly can be said to imply, that endeavours are made to forward the goods and the cars to the greatest possible extent, on electrified routes, and in long-distance trains to avoid sections of the line with steep uphill gradients as well as such haulage routes, which would entail re-loading of the goods. Bearing these considerations

in mind, the railway administration publishes every year special « Route Regulations » for haulage on the State Railways. The choice of route for haulage affecting private railway sections, which is determined by special government regulations, is based on a comparison of freight rates on various possible routes, whereby as a rule the route, which offers the lowest average freight rate for the different rate classes, is given the haulage. When the private railways are nationalized, the State Railway's route regulations will be applied on these sections of the line and here as well the point of view of operating costs will decide the choice of route.

The car scheme determines the need of cars of various types for haulage of goods in different station relations.

As regards the question of goods in car-loads, the number of cars required of different types (open, closed or special cars) is decided by the user of the traffic-route, who orders cars from the railway for loading the goods and who afterwards hands over the loaded cars to the railway for haulage. On the other hand, the railway itself decides the number of cars of different types necessary for the loading of goods in less than carloads (LCL).

With the settlement of the routes and the car schemes is also decided how many cars of different types are to be loaded and unloaded at every station as well as on which sections of the line and in which directions these car consignments shall be forwarded and what quantities of goods and what number of cars shall be re-loaded at different stations. Finally from the figures as to the number of cars required for loading and emptied by unloading, it can be estimated at every station the surplus respectively shortage of cars at the station and thereby the number of empty cars, which must be sent from one station to another to cover the shortage of cars arising there.

The train scheme partly regulates the size and combination of the train, partly the train's forwarding according to the time-table. In the former case it is a question partly of planning which cars are to form every train at its station of departure, partly which cars are to be coupled on or off at different stations. In the latter case, it is specially necessary to consider the division of the trains into local goods trains and long-distance goods trains.

The locomotive scheme is intended to provide the trains required in the train scheme with the necessary traction power of suitable types and in the most practical way to combine the employment of the locomotive for the different trains.

The various part schemes discussed here, which, as has been mentioned, together form the operational scheme, are interdependent. Thus, for example, the choice of a certain haulage route for LCL-goods is related with the choice of type of car and type of train. The operational planning, i.e. the formation of the different schemes, must therefore take place at one time and with the object of attaining such a combination of route-, car-, train- and locomotive schemes that are the most advantageous for the intended *transport standard* from an economic point of view.

B. Operational quantities.

Starting from the operational scheme it is possible to calculate measurement figures for certain factors, hereafter termed *operational quantities*, on which the expenses for the completion of the haulage order are primarily dependent.

The primary operational quantities are the following :

Nettotonkm., divided up for different sections of the line, types of trains, types of power, types of traffic, etc.

Carkm., similarly divided up for different sections of the line, types of car, types of train, types of power, types of traffic, etc.

Dispatched and received loaded respectively empty cars, divided up for different stations, types of traffic, types of car, etc.

Shunting on route for different stations and giving the type of car and type of traffic.

Trains dispatched for different stations and different types of train.

Trainkm. for different sections of the line, types of train and types of power.

Locomotivekm. for different sections of the line, types of train (including shunting) and types of power.

The haulage order can be defined as the haulage service ordered by the customer concerned, i.e. the moving of a certain traffic object from its station of departure to its station of arrival as well as services of other type's performed in connection herewith. The services of different types, which the railway renders for the completion of a certain haulage order, have been grouped together under the name of *operational service*.

The sum of all these separate haulage orders respectively haulage services is termed the *total haulage order* respectively the *total operational service*. The accepted measurement for a haulage order consists of the traffic object's weight (ton) and the tariff stretch's length (km.) or combined to one quantity, the number of tarifftonkm. In order that the total haulage order shall be completely determined, it is however not sufficient to state the total tarifftonkm. only or even how the total ton figure is distributed over different tariff distances but for every type of traffic, type of goods and station relation must as well the quantity of goods as this quantity's distribution for separate times of the year be given.

The *primary operational quantities* can be obtained directly from the various part schemes, which are included in the operational scheme. By means of the operational planning it is even possible to determine the remaining operational quantities influencing expenses.

The method given above, whereby the relevant operational quantities are determined on the basis of operational planning, must as a rule be employed in the calculation of the expenses in a new traffic situation. The application of the method will in most cases be very arduous, as it requires the drawing up of route-, car-, train- and locomotive schemes for all the station relations occurring. As the various administrative organizations belonging to the railway company have longstanding experience of similar planning as regards train-, car- and locomotive schemes, etc., for different timetable periods, no greater practical difficulties should arise in carrying this out.

In reality it should only be with regard to *greater variations in traffic* (30 % or more in size greater than the initial situation) that operational planning will entail any more serious burden of work for the administrative organizations of the railway.

If it is a question of *lesser variations in traffic*, which cannot be expected to influence the existing route-, car-, train- and locomotive scheme, or if it is a question of variations in traffic only on a

certain limited part of the *track network*, it would seem that this operational planning would be comparatively simple to carry out. For these lesser variations in traffic it should also be possible in many cases to use the following simplified method for the determining of operational quantities, which is based on a simplified hypothesis concerning the structure of the haulage order.

This simplified method is *partly* based on the supposition of *constant station relation structure* for the type or types of traffic, which are the objects of the investigation, i.e. it is assumed that the transport quantities in *all* the station relations increase or decrease with the same percentage in relation to the initial situation, *partly* on the supposition of *constant methods of transport*, that is to say the goods are assumed to be hauled in the new traffic situation in the same type of car, on the same sections and in the same sorts of trains, as in the initial situation. Both these special assumptions can be summarized in the term *constant haulage structure*.

Thus no regard is taken with this method to possible transfers in the new traffic situation of different types of trains and types of cars, as for example the possible shortening of the route in the new traffic situation, etc. On the other hand, it is possible to consider such changes in the employment of cars and trains, as could be a consequence of variations in the magnitude of the haulage order.

Thus the number of cars dispatched at the stations of dispatch does not increase at the same rate as the haulage order but somewath more slowly as a consequence of the cars being able to be employed better as a rule, when the quantity of goods dispatched becomes greater. The same is the case as far as the trains are concerned. The maximum size of the trains as to the number of cars per train and the gross ton car weight per train are controlled by the safety regulations. This maximum capacity per train can, however, only be employed fully on the lines that have the most traffic, during certain seasons of the year and at certain peak periods and then perhaps only for some of the trains in traffic there. Thus in most cases train capacity is not fully utilized. The number of trainkm. will therefore not increase proportionally to the number of cars dispatched but instead considerably more slowly.

The calculation of the number of trainkm. in the new traffic situation can probably be made most suitably by means of a statistical analysis of the loading conditions in trains of different types on a representative selection of track sections of different types. On the basis of the relations hereby obtained it should be possible to form quite a good conception of the probable number of trainkm. in the new traffic situation.

The method given above is suitable above all when it is a question of calculations, concerning relatively small variations in the haulage order, and should give a more exact result, the less the variations in the haulage order are.

In the question of the calculation of expenses for *special haulage orders*, which only affect certain parts of the railway network, the operational planning is usually very simple, as most of the factors which influence expenses do not undergo any change. For these calculations, which principally should be necessary as a basis for special reductions in freight rates, it seems to be quite satisfactory to draw up a dispatching plan,

including amongst other things the number of loaded cars and in which trains they should be dispatched.

C. Calculation of expenses for a certain alternative.

The calculation of expenses can take place in two different ways, namely *partly* in the form of *expenses determined in the form of a budget,* which implies that for every branch of the railway an estimate (budget) is compiled for the new traffic situation, *partly* in the form of *statistical calculation of expenses* for the new traffic situation.

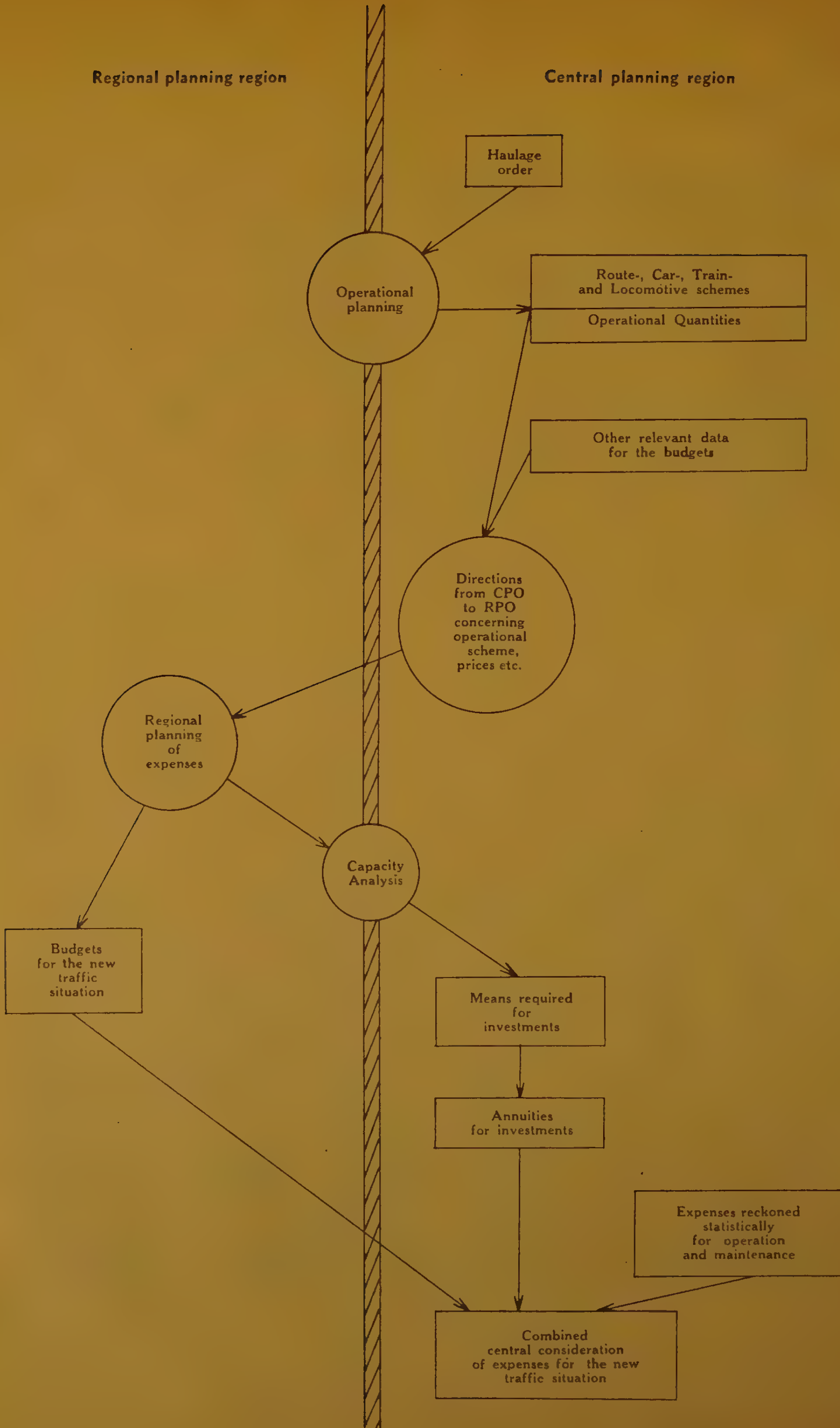
The diagram given hereafter shows how this calculation for a new traffic situation can be organized. The organization drawn up there presupposes *partly* the existence of an organization in the railway company responsible for these calculations, here referred to as the *central planning organization* (abbreviated to CPO), *partly* that the various division and section authorities in the operational service and the principal workshops co-operate in the calculation of costs. The authorities, just referred to, are alluded to hereafter as the *regional planning organizations* (abbreviated to RPO).

The organizational diagram is drawn up in such a manner that, on the right-hand side of same can be found the tasks, etc., which are attended to by the central planning organization, while on the lefthand side are stated the tasks, which are attended to by the regional planning organization. In addition certain tasks occur on the dividingline between the central and the regional planning regions in the diagram, which are intended to be handled with the co-operation of both the types of planning organizations. The course of the calculations for a new traffic situation can be summed up in the following manner.

On the basis of the haulage order, with which one has to calculate in the new traffic situation, the central planning organization in co-operation with the regional planning organizations carries out the operational planning, which has been described in more detail in the previous sections. The operational planning results in the drawing up of an operational scheme, including route-, car-, train- and locomotive schemes for the new traffic situation, besides which operational quantities requisite for the calculation are reckoned.

The central planning organization then informs the regional organizations as to the further details and data concerning the operational plan as well as wages and prices for materials, which should be applied in the new traffic situation. On the basis of these particulars, the regional organizations then draw up budgets for their spheres of activities, with regard to the expenses for operation and maintenance in the new traffic situation. This method of procedure is mainly in accordance with the method that is used annually for the drawing up of suggestions for the budget. In addition, however, the regional planning organizations, guided by data received from the central planning organization for the traffic in the new traffic situation, try to estimate if the capacity of the existing structures in the planning district concerned is sufficient for traffic in the new situation. This so-called *capacity analysis,* which is made in co-operation with the central planning organization, gives particulars as to existing needs for investments in the new situation.

The calculation of requirements for means for the necessary investments and


Regional planning region
Central planning region
Haulage order
Operational planning
Route-, Car-, Train- and Locomotive schemes
Operational Quantities
Other relevant data for the budgets
Directions from CPO to RPO concerning operational scheme, prices etc.
Regional planning of expenses
Capacity Analysis
Budgets for the new traffic situation
Means required for investments
Annuities for investments
Expenses reckoned statistically for operation and maintenance
Combined central consideration of expenses for the new traffic situation

with what annuities these investments should be included in the calculation for the new traffic situation are, however, the tasks of the central planning organization.

The *statistical calculation of expenses* forms a complement to the regional costs planning, and both methods should be employed in order to obtain a satisfactory determination of the probable expenses in the new traffic situation. The statistical method is based on a regression analysis of the connection between the operational quantities and expenses in different service districts and types of expenses, and it will therefore be of great assistance in the regional costs planning.

The statistical calculation is made by the central planning organization and serves principally as a control for the budgets worked out by the regional planning organizations for the new traffic situation.

As the *final measure in the calculations of the expenses* for both the traffic situations, the central planning organization compares the amounts for different branches of service and accounts, which have been obtained by the budgets, with those which have been calculated according to statistical methods and decides from them with what amounts the different items of expenses in the respective traffic situations should be included in the budget.

[621 .431 .72 (.85) & 625 .285 (.85)]

Light-weight railcars, Central Railway of Peru,

by J. L. KOFFMAN,

Dipl.-Ing., M. S. A. E., A. M. I. Loco. E.

For the last ten years or so the Peruvian Corporation has consistently pursued the policy of replacing steam traction by Diesel railcars on its railways. Among these the Central Railway is the most important and from the traction point of view also the most difficult one. As already mentioned in a previous article (1) (*) after leaving the terminal at the port of Callao, the vehicles face a continuous climb for 172 km. up to an altitude of 4 781 m. above sea level at Galera. From here the line descends to 3 500 m. at the railhead at Huancayo some 345 km. from the coast. Besides negotiating extended grades of 1 in 22 to 25 and numerous curves with a radius of just over 100 m., which feature this highest railway of the world, the operation of railcars is furthermore made difficult by the fact that due to the increasing rarification of the atmosphere at higher altitudes, the power output of internal combustion engines is reduced by approximately 1 per cent per every 100 m. of altitude.

In view of the success achieved on this railway with a number of steam railcars converted for Diesel operation (2) and powered by supercharged engines supplied by S. A. Adolph Saurer of Arbon, Switzerland, it was decided to base the design of five new vehicles on the use of Saurer six-cylinder 14.3 litre type BXDL engines fitted with a Büchi turbocharger. Since both the engine and the method of supercharging have been described in the technical press (3) it will be sufficient to mention that while the continuous output of the supercharged engine is 200 H.P. as against 150 H.P. unsupercharged (Fig. 1) the superchargers are designed to ensure a power output of 140 to 150 H.P. at the highest

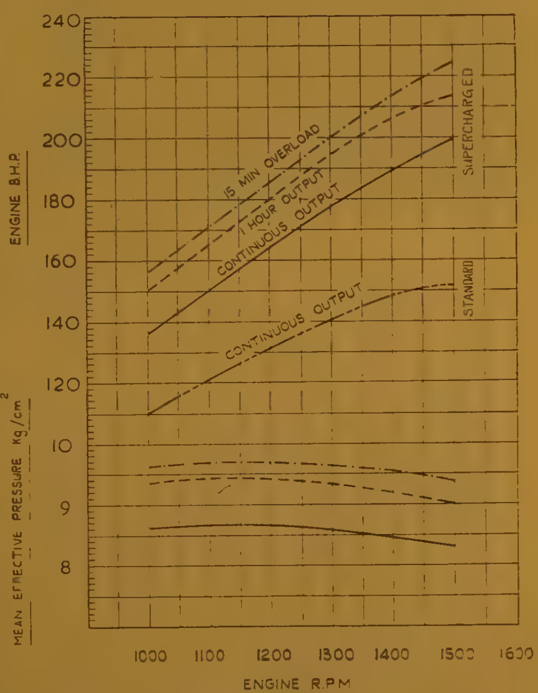


Fig. 1. — Performance curves, Saurer BXDL engine.

(*) Numbers in parantheses refer to the Bibliography at the end of the article.

altitudes encountered, as against only about 85 H.P. obtainable when unsupercharged.

In order to meet the traffic requirements for considerably improved speeds it was necessary to keep the weight of the cars, built by D. Wickham & Co. Ltd., and designed to accommodate 50 first-class passenger (as well as a small luggage compartment and a W.C.), to $15\frac{1}{2}$ tons when ready for operation and about 20.5 when fully laden. To achieve this solid-drawn square tubular sections were used for the body framework, no separate underframe being employed. The longitudinal and cross members are mainly $2^3/_8$ in. wide, $^1/_8$ in. thick square tubes, while $1\frac{3}{4}$ in. wide, $^1/_8$ in. thick square tubes are used for roof cross members, $1\frac{3}{4}$ in. by $^1/_8$ in. pressed steel channels being used as longitudinal members ([4]). The cars (Fig. 2) have an overall length of about 52 ft. the height being 10 ft. 6 in., whilst the height from floor to roof (inside) is 6 ft. $5\frac{1}{4}$ in. The bogie centres are pitched at 34 ft. $4\frac{1}{4}$ in., the wheelbase of the power bogie being 8 ft. 3 in., and that of the trailing bogie 6 ft. Since two of the cars had to be designed for experimental service on a branch line of the L.N.E. Railway the body width had to be limited to 8 ft. 8 in. which made it impossible to arrange the driver's compartment alongside the engine, and because of this an automobile-type bonnet had to be provided over the engine. This reduces the available car length to about 45 ft. The engine drives one axle of the vehicle via a fluid flywheel, a four-speed Cotal type 125 mkg. transmission, Layrub coupling and a two-speed reversible axle drive. The latter was incorporated because of the obvious necessity of running the car at lower speeds uphill than down, and the inability of the transmission to run in intermediate gears at full load for 2 to 3 hours on end without incurring excessive temperatures due to oil churning losses and the consequent necessity of providing adequate oil cooling circuit and also due to the possibility of undue transmission wear when called to deal with the heavy tórque loads encountered in intermediate gears. The maximum speeds permitted by the two axle drive ratios are 42 and 98 km./h. respectively with the Cotal transmission in direct gear.

Fig. 2. — Light-weight railcars, Central Railway of Peru.

The cars are arranged for multiple unit operation, the engine throttle being

controlled electro-pneumatically, the same being the case with the reversing gear and the two speed axle drive. The axle drive control circuits are interlocked with the control circuit of the Cotal transmission which cannot be operated until the axle drive circuits are completed. The Cotal transmission being of the epicyclic type incorporating electromagnetic clutches is particularly suitable for multiple unit operation. Sanders are provided at the driving wheels only and these are arranged for multiple-unit operation with the help of electro-magnetic valves.

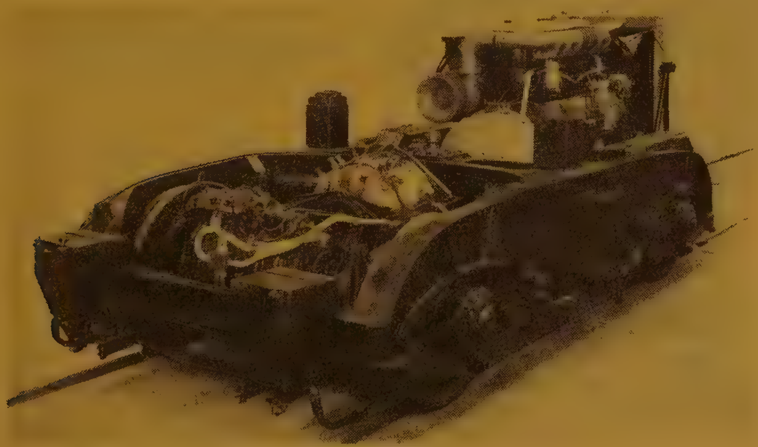


Fig. 3. — Power bogie.

The clasp brakes were designed to facilitate adjustment and inspection. Westinghouse equipment was used throughout, the brakes being of the straight air type with emergency features and self-lapping brake valve at the driver's stand controlling two 8-in. pressed steel brake cylinders mounted on the car body. Compressed air for the brakes, sanders and axle drive control is supplied by a Saurer compressor driven by the engine in tandem with the fuel pump. In addition a Westinghouse compressor is mounted on the trailing bogie, the drive being via belts from one axle, so that when the engine is working hard and the vehicle is running slowly, as on an up grade, the engine compressor will keep up the air supply, while when descending grades with the engine idling and the car running fast, the axle driven compressor will be mainly relied upon.

Except for the sanders, dipper switch for electric headlamp and signal horn, all controls are hand operated. A dead-man switch stopping the engine and applying emergency brake is incorporated in the throttle control lever. A foot-operated switch is provided in parallel with that of the hand throttle.

Automatic couplers are provided at the rear end of each car only. The windows at the driver's compartment are protected by bars against damage by vultures often sitting on the permanent way and rising in front of the car.

The design of the bogies (Figs. 3

and 4) departs from conventional lines in many ways, and because of this they are dealt with here in somewhat greater detail.

Due to considerations stated in a previous article published in this *Bulletin* ([5]) the use of conventional hornblocks has been dispensed with in favour of

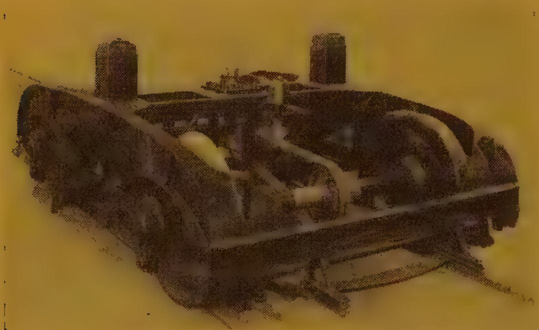


Fig. 4. — Trailing bogie.

radius arms. The axles are carried in self-aligning roller bearings and the axleboxes are located in the bogie frame by means of radius arms secured via Silentbloc bushes which allow a small radial and longitudinal displacement. The bogie frame is carried on half elliptic springs secured to the axlebox by trunions. The entire design is identical to that of the railcars supplied to the Kenya and Uganda Railways and Harbours Administration and dealt with in Reference ([5]).

In addition to resulting in lighter and cheaper bogies, both so far as first costs and maintenance expenses are concerned, this design also results in improved riding qualities, for as shown by HEUMANN ([6]) and a number of other investigators, the wave length of the sinusoidal path pursued by a wheel set along the track can be increased by securing the two axles of a bogie parallel to each other. HEUMANN has derived the equation of the elongation factor E by which the wave length of a single wheel set is increased if it is positively secured in a bogie frame so that

$$l' = l \cdot E \quad . \quad . \quad . \quad . \quad (1)$$

where

l' = wave length of path of bogie centre;

l = wave length of path, free wheel set;

E = elongation factor.

The actual equation, which applies to trailing bogies with equal wheel loads only, is given in Fig. 5.

Here :

a = bogie wheelbase;

r = wheel radius (for Fig. 5 : r = 1 ft. 4½ in.);

s = half the distance between rolling circles of a wheel set;

β = coning angle of tyres;

μ_s = slip friction coefficient.

It will be noted from Fig. 5 that for a bogie with a 6 ft. wheelbase E = 1.7 whilst for an 8 ft. 3 in. wheelbase E = 2.1 and this will have a beneficial

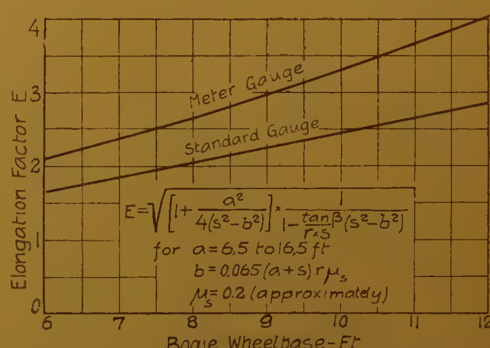


Fig. 5. — Elongation factor in accordance with Heumann.

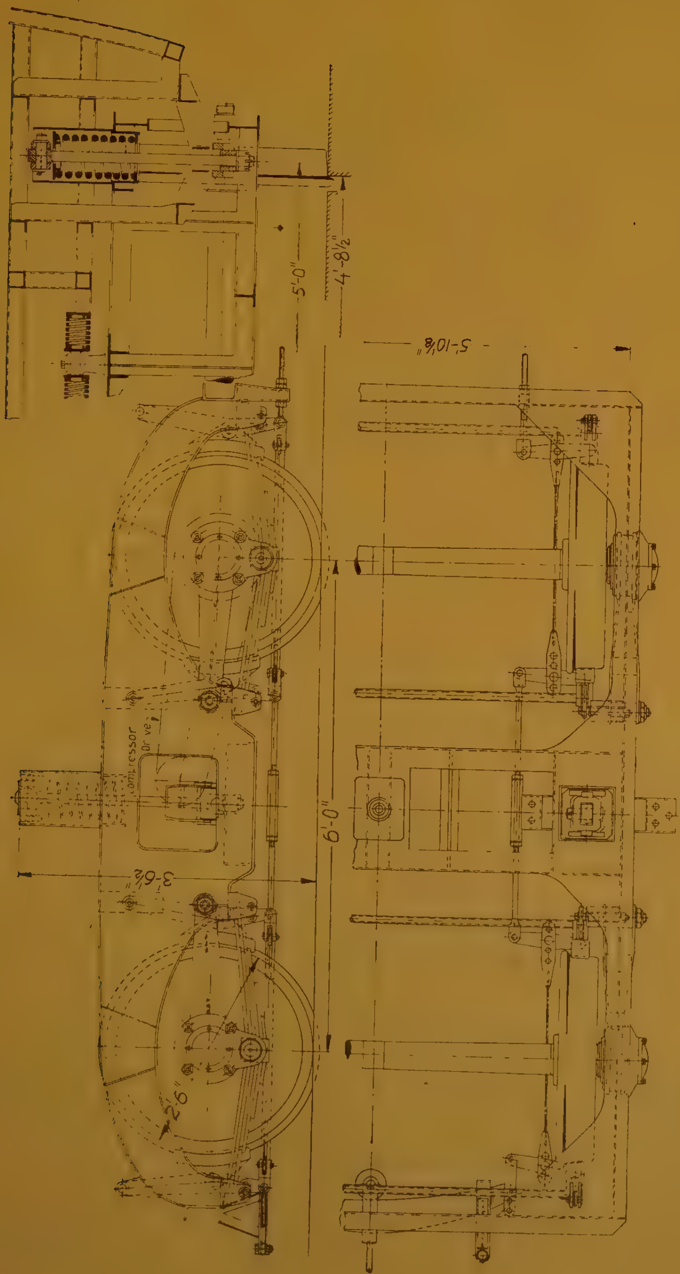


Fig. 6. — Trailing bogie.

effect by reducing the frequency of the lateral disturbances transmitted to the car body.

In view of the fundamental importance of HEUMANN's investigations upon future bogie development a careful study of his article mentioned above and his subsequent publications (see Ref. 5) on the subject of bogies with rigidly secured axles is recommended to all concerned with the design of railway vehicles.

The suspension of the car body on the bogie is of a somewhat unusual type Fig. 6. The body is carried on each bogie by means of two helical springs, one at each side of the bogie frame. Each spring is carried in a container and supports a square plate which in turn carries a universal joint. The latter carries a rod which passes through the spring downwards and carries at the lower end another universal joint which supports an anchor-shaped bracket. This bracket supports the car body with the help of extensions provided on the body frame. The purpose of the spring housing and the closely fitting plate on top of the spring is to act as a guide. Houdaille hydraulic shock absorbers are provided on each side of the bogie to dampen excessive vibration encountered particularly when the natural frequency of the springs happens to coincide with the frequency of the car passing over rail joints.

This type of suspension has by itself the advantage of lightness, because it does away with the bolster, and cheapness for the number of parts is somewhat reduced. In addition it has the very considerable advantage of permitting the use of very long swing links — in this case 25 inches — but on the other hand it has the disadvantage of centralising the load at the highest stressed point of the bogie frame whilst in addition the long swing links, extremely desirable for other reasons, do not afford sufficiently high centering forces against lateral displacement. Because of this helical springs were used at the centre pin to control lateral movement of the bogies.

The wheelbase of the power bogie amounts to 8 ft. 3 in. in order to accommodate the power plant. This wheelbase is about the maximum tolerable on the Central Railway which abounds with curves of radii down to 110 m. The wheelbase of the trailing bogie was limited to 6 ft. mainly in order to keep the weight down.

It might be mentioned here that the type of body suspension used here is not novel, for it has been previously used with a number of Sentinel-Cammel steam railcars supplied to the Central Railway and because found to be satisfactory was propagated with other railcars built for this line. But long before this time bogies of basically similar design were introduced by William Dean on the Great Western Railway. With this design (Fig. 7) four links on hemispherical bearings are suspended from brackets on the outside of the bogie frame near the centre and these carry two transverse bars on volute springs. The body and underframe are mounted on the bogies by means of stanchions which project downwards from the underframe and are attached to the extremities of the transverse bars. The centre pivot pin is rigidly fixed to the underframe and engages with a bush which is capable of a limited amount of lateral travel on the bogie frame.

In a similar design of still earlier date the transverse bars are situated at either end and the stanchions are at the four

corners of the bogie. These two types of bogies were introduced many years ago, but there are a large number in service to-day ([7]).

Again a similar link arrangement was used with the trailing bogie of the 0-C-2 locomotive built by Sigl in 1888 for the Austrian Kaiser-Ferdinand Nord Bahn ([8]).

Since bogies with suspension of the « Peru » type will be built for further vehicles and since this type of suspension might be used elsewhere some aspects of that the equivalent pendulum length — which determines the natural frequency of the system — is sinonumous to the length of the swing hanger. To illustrate the point consider the extreme case where the inclination of the hangers is so great that the intersection of their centre lines is at the height of the centre of gravity of the body which they support. Then for a very small oscillation the centre of gravity will remain fixed, because it is also the centre of rotation of the body.

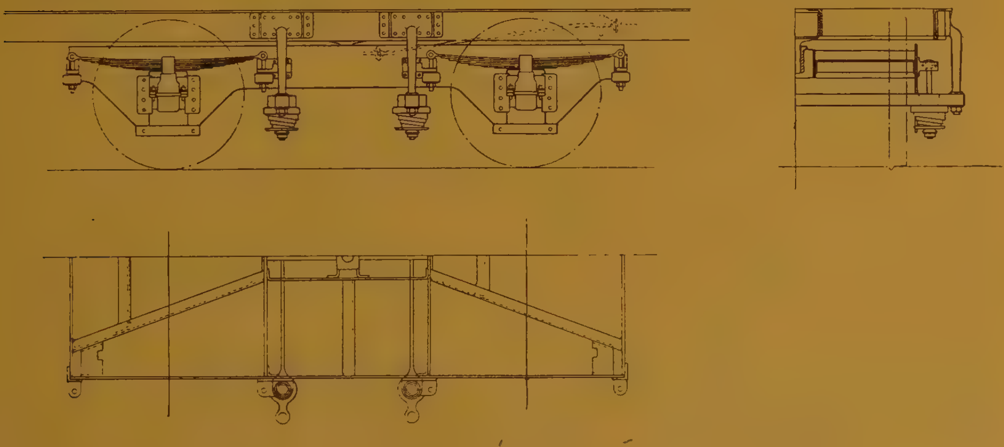


Fig. 7. — Dean bogie.

the mechanics of this design will be briefly dealt with.

In the present case rather long swing hangers were employed to ensure a low lateral frequency, whilst the hangers were arranged vertically since this may be just as effective as when inclining the hangers. As pointed out by Skutsch ([9]) and Ronai ([10]) the natural frequency of inclined hangers depends to a considerable extent upon the location of the centre of gravity and this will vary to a considerable extent with light weight vehicles depending whether they are empty or loaded, and it is only with straight hangers

However much lateral force acts at the centre of gravity it will not cause the hangers to swing because their swinging would not allow the centre of gravity to move sideways. If the system oscillates it will do it by the centre of gravity oscillating vertically up and down as the body swings on the hangers. In this case the hangers are completely ineffective as a cushion against side movements of the bogie. Although this condition is extreme it gives some insight into the factors which affect a practical design which approaches more or less nearly to this condition.

If

l = length of each hanger;

c = spacing of bottom pins;

h = height of centre of gravity above bottom pins;

b = horizontal distance between top and bottom pins (b positive for converging hangers and negative for diverging hangers, b = 0 for straight hangers, $b = l \cdot \cos\varphi$ for inclined hangers);

a = vertical distance between top and bottom pins ($a = l$ for straight hangers, $a = \sqrt{l^2 - b^2}$ for inclined hangers).

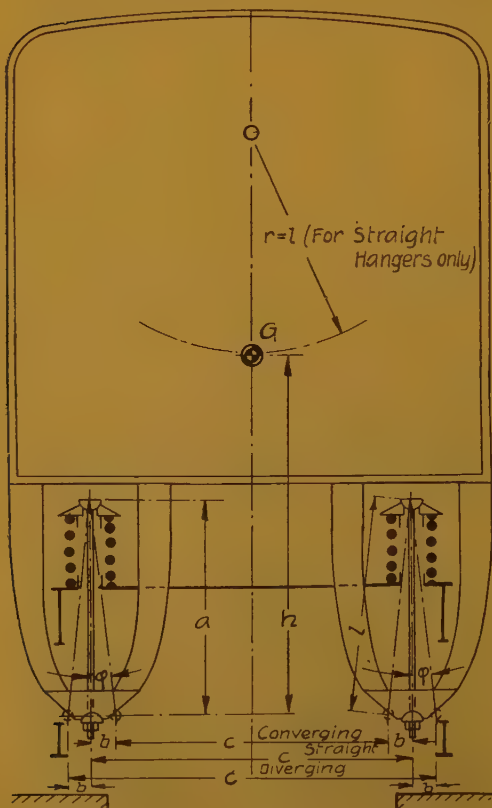


Fig. 8. — Scheme of Peru railcar suspension.

The equation of the instantaneous radius of rotation r of the path of the centre of gravity G (Fig. 8) for both the positive values of b for converging hangers and negative b values for diverging hangers, is :

$$r = \frac{a(ac + 2bh)^2}{c^2l^2 + 2b^3c - 4ab^2h}. \quad (2)$$

For the cars dealt with here l = 25 in. whilst h is assumed to 45 in. The values of r and the resultant natural frequency f are shown in Fig. 9 for values of b varying between ± 10 in. It will be ob-

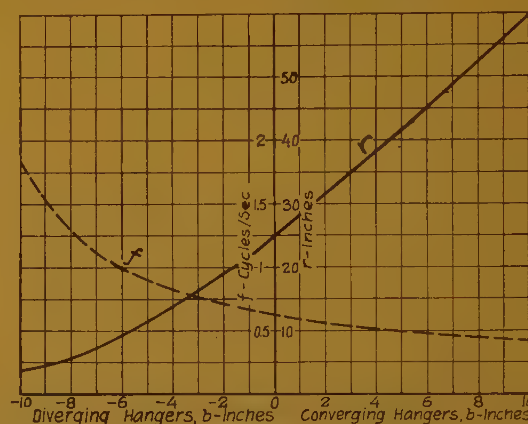


Fig. 9. — Characteristics of inclined hangers.

served that depending whether the hangers are converging or diverging the lateral restraint decreases or increases rather quickly whilst the natural frequencies decrease or increase accordingly. It is important to note that when the hangers are inclined the body must rotate as it swings from side to side. It follows that if the bogie is suddenly displaced laterally the body must either rotate very suddenly, so that a shock is felt, or the rotation must be dampened by the springs provided either in the hangers or

as bolster springs between hangers and body. If the springs are all between the axles and bogie frame then a sudden lateral motion of the bogie will cause a sudden change in angle between bogie frame and car body and as both of these have inertia a shock will be felt.

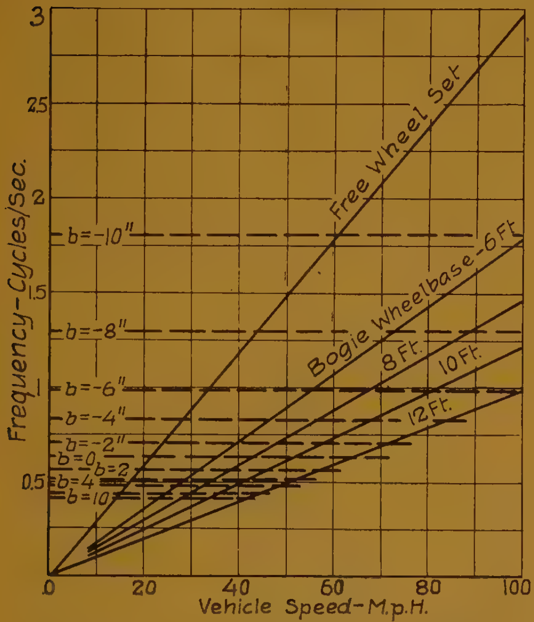


Fig. 10. — Lateral frequency of bogies and hangers.

The natural frequency values shown in Fig. 9 are plotted in Fig. 10 together with the frequencies of the sine path of the bogies running on straight track. The latter values were calculated on the basis of the E values Fig. 5. It will be noted that the natural frequency of the 25 in. long straight hangers ($b = 0$) coincides with the lateral frequency of a 6 ft. bogie at a vehicle speed of about 36 m. p.h. and this will result of considerable hunting of the car body. Should this speed happen to be the cruising speed of the vehicle it would be desirable to avoid synchronism at this point and a remedy might be found in altering the value of l, or inclining the hangers. In any case this aspect of the design should be analysed before settling details.

The effect of the height of the centre of gravity h upon r and f is illustrated in Fig. 11 for a hanger inclination of $\varphi = 10°$ and l of 25 in. Whilst of no effect with straight hangers the value of h might have considerable bearing upon

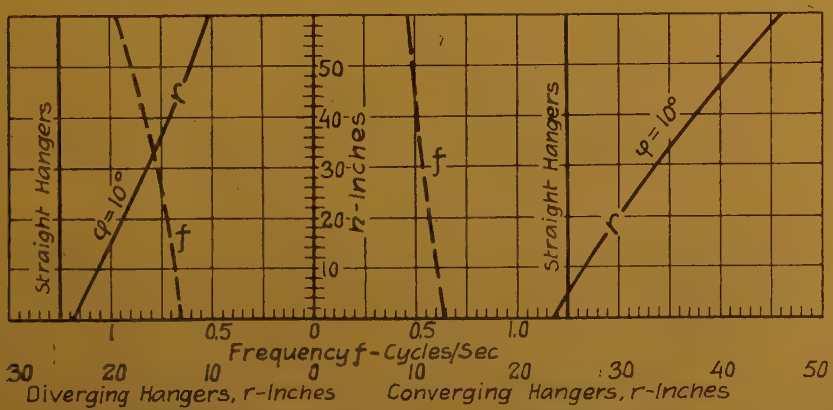


Fig. 11. — Characteristics of inclined hangers, as affected by the height of centre of gravity.

the riding qualities when inclined hangers are used.

The purpose of the bogie is, amongst other things, to ensure a smooth running through curves and to achieve this it must have a certain minimum degree of freedom. If the bogie is unduly restrained from turning freely upon entering curves then a certain shock may be expected, and if the restraining action is maintained throughout the passage through the curve then additional wear of wheel flanges and rails is to be expected. On the other hand a certain amount of damping is desirable so far as the sinusoidal path of the bogie in the straight is concerned, a reason for supporting the body directly on the check plates of orthodox bolsters. How does this type of suspension behave in curves and in the straight when considered against the background of the above requirements ?

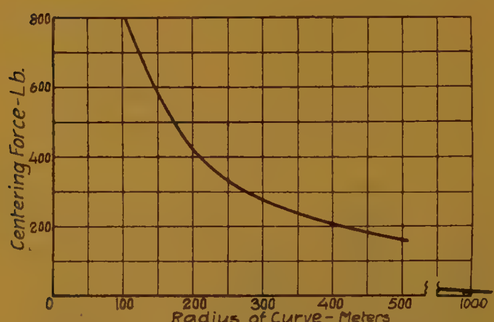


Fig. 12. — Centering force due to hangers.

The answer to this is given in Fig. 12 showing the centering forces (at the distance *c*, Fig. 8) plotted against the curve radius for the bogie Fig. 6. The forces follow a hyperbola, the values rising rapidly as the curve radius diminishes. On the other hand the forces set up to oppose the sinusoidal motion of the bogie running in the straight are small. The curvature of the sinus wave can be represented by a circle with a radius of 1 100 m. and for this the centering force is only 7 lbs. Because most curves are provided with cubic parabola transition curves the centering force excerted by the hangers will rise gradually as the vehicle moves along and no shock will be experienced by the passengers, but all the same the desirability of making the hangers as long as possible is clearly indicated by the above consideration. In addition the provision of anti-hunting dampers may be found to be desirable.

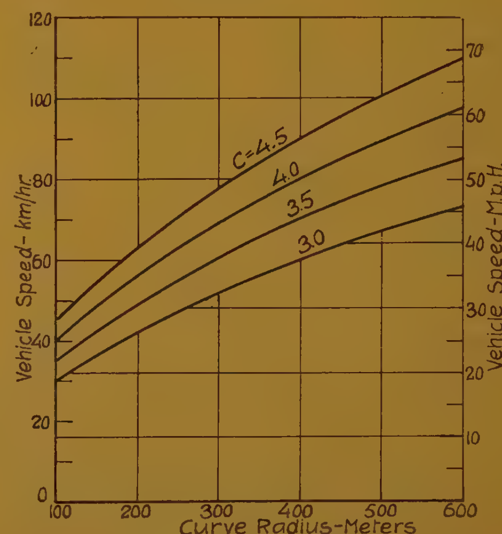


Fig. 13. — Speed in curves.

With bogies with which the body rests on pads carried by the bolster it is necessary to overcome a force equal to the product of weight and coefficient of friction between pads when entering a curve and when leaving it and thus no forces are acting upon the wheel flanges due to this cause when passing through the curve.

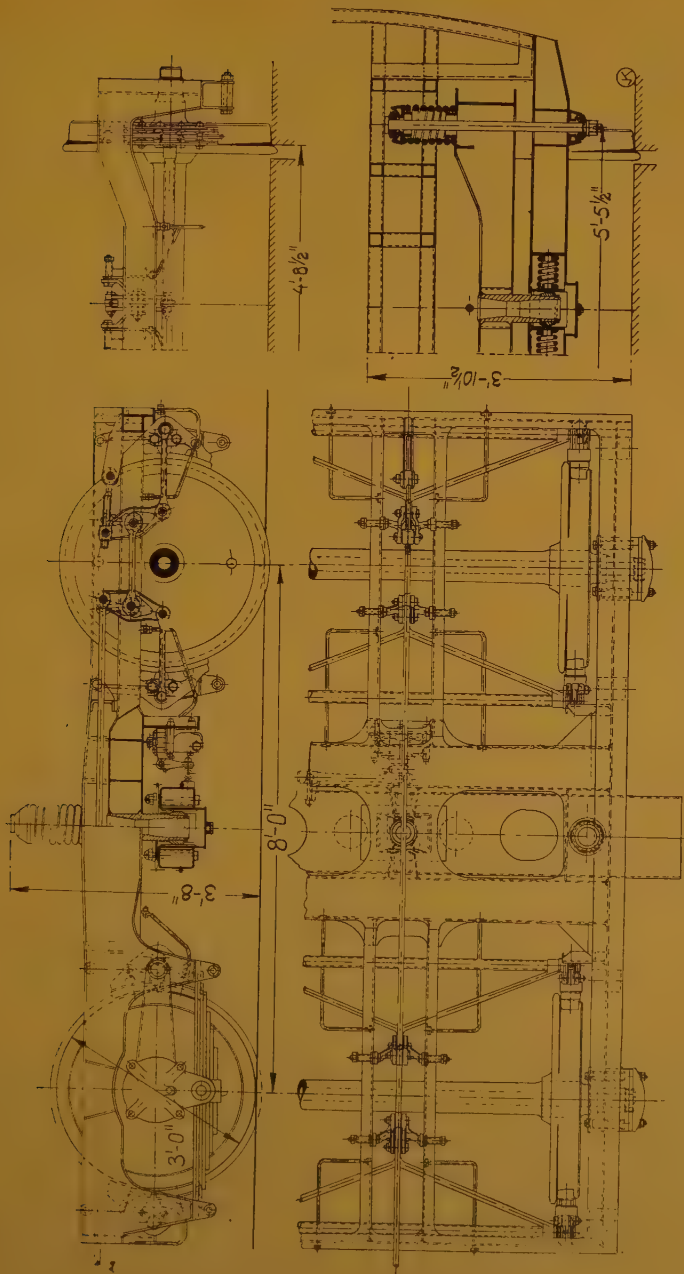


Fig. 14. — Proposed design of trailing bogie.

The provision of long hangers, particularly desirable with bogies of this type results in a drawback so far as running through curves is concerned. Practical experience indicates that the unbalanced lateral acceleration (i.e. acceleration not met by superelevation) due to centrifugal forces acting on the vehicle passing through curves should not exceed $p = 0.6$ m./sec² (11). The values of superelevation are frequently determined for standard gauge from the equation based on this value for p

$$u = \frac{11.8V^2}{R} - 92 \quad . \quad . \quad (3)$$

where

u = superelevation [mm.];

V = vehicle speed [km./h.];

R = curve radius [m.].

The constant value of 90 is mostly used in place of 92.

Conversily the maximum speed of standard gauge vehicle running through suitably superelevated curves is given by the equation :

$$V_{max} = \sqrt{\frac{R}{11.8}(u + 90)} = C\sqrt{R} \quad (4)$$

where

$$C = \sqrt{\frac{u + 90}{11.8}}$$

The values for C normally do not exceed 3 to 4, being mostly limited by the ability of the locomotives to enter and leave curves without shock, but values of up to 4.5 were maintained by railcars. The vehicle speed curve radius relation for a number of C values are shown in Fig. 13.

Due to loading gauge restrictions the lateral displacement of the car body in the present case must be limited to 1 inch. With 25 in. long hangers the lateral force met at 1 inch lateral displacement is equivalent to about 4 % of the load, whereas the force equivalent to the p value mentioned above is equivalent to about 6 % of the vertical load. In addition the matter is made worse by the frequent absence of proper transition curves on the Central Railway. In other words a shock would be experienced by the passengers. To avoid this lateral control helical springs are provided at each side of the centre pin and these have proved to be entirely satisfactory.

The design of bogies of this type may be improved by simplifying the details of the body suspension, at the same time bringing the height of the centre pin closer to the centre line of the axles, thus reducing the tilting moment to which the bogie frame is subjected when dealing with tractive forces. The possibilities offerred along these lines are indicated by the bogie design Fig. 14. Here the lateral guidance of the body suspension has been left to the transverse stiffness of the helical springs. The necessary spring characteristics may be readily determined with the help of the graphs Figs. 15 and 16 (12). The hanger joints have been simplified and provision made for ready replacement of suspension components without the necessity of lifting the car body.

At the present the cars cover the run from Lima to Oroya in 4 hours 33 minutes which is 2 hours better than the fastest steam train. It is proposed to make a timetable time of 5½ hours against 8½ hours required by steam traction. The down run is accomplished in 4 hours 40 minutes as compared with 5 hours 40 minutes required by steam trains.

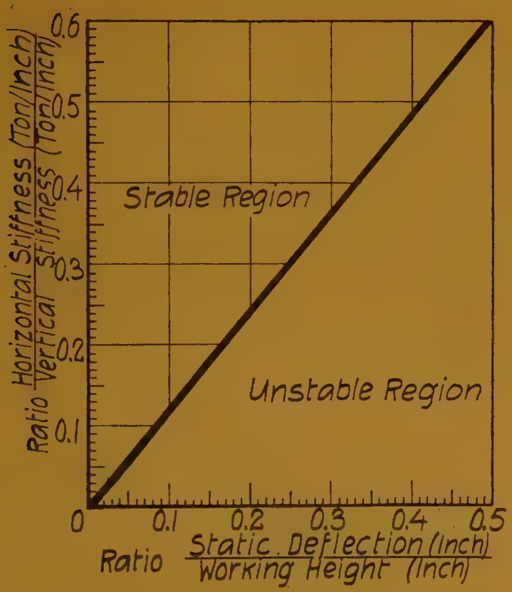


Fig. 15. — Stable and unstable regions for helical springs dealing with lateral and compression loads.

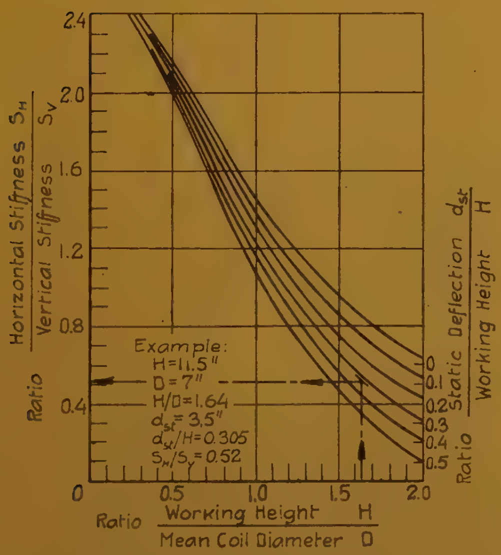


Fig. 16. — Relation between vertical and horizontal spring stiffness.

A problem of considerable interest in the operation of mountain railways is that of braking when descending long steep grades, a problem which, as might be imagined, is particularly acute on the Central Railway. The thermal aspects of this problem have been previously dealt with by the late W. KLEINOW ([14]) and by Prof P. MULLER ([15]), but the resulting considerations are of not much help in the case of vehicles descending at constant road speeds, since they deal mainly with the problem of bringing trains to a standstill, and then only in very general terms.

Before, however, dealing with this matter we must consider the values of the coefficient of friction between brake block and wheel, a subject on which the results of a number of investigations are available though many of these were carried out on rigs and models. These were summarised by the author some time ago ([16]). In the meantime very extensive tests were carried out in the U.S.S.R. on four-wheel and bogie goods carriages running on an experimental circular track having a radius of about 950 m. ([17]).

The results of these investigations indicate that for a cast iron block having the standard (wagon) U.S.S.R. face dimensions of $43 \times 8 = 344$ cm² the coefficient of friction can be expressed by the following equation ([18]) :

$$\mu = 0.6 \frac{16P + 100}{80P + 100} \times \frac{V + 100}{5V + 100}. \qquad (5)$$

where

P = brake block pressure [tons];

V = vehicle speed [km./h.].

From the results obtained during the above mentioned tests it is possible to deduce an equation for μ which is ap-

plicable for known values of specific brake block pressures

$$\mu = \frac{38.4}{\sqrt{p + 0.72}\ (V + 53.6)} \quad . \quad . \quad (6)$$

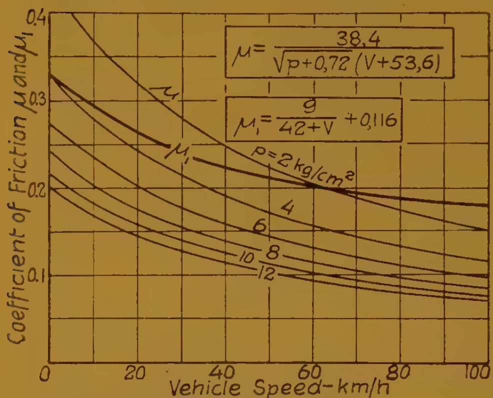


Fig. 17. — Coefficient of friction between wheel and rail and brake block and wheel.

where

p = specific brake block pressure [kgr./cm²];

V = vehicle speed [km./h.];

0.72 = empirical constant.

The values of versus V are plotted for a number of p values in Fig. 17.

The coefficient of friction between dry rails and rolling wheels can be expressed by the following equation ([19]):

$$\mu_1 = \frac{9l}{V + 42} + 0.116 \quad . \quad . \quad . \quad (7)$$

where V = vehicle speed [km./h.].

With the help of equations (6) and (7) we can determine the brake ratio r as follows: Let the wheel load of one axle be q, the number of brake blocks per axle n, and the brake pressure per block P. Then we can write: $n\mu P = q\mu_1$, and consequently

$$r \leqslant \frac{nP}{q} \leqslant \frac{\mu_1}{\mu}$$

To simplify the subsequent thermal calculations we shall consider the wheel tyre as separated from the rest of the wheel, i.e. we assume the tyre as surrounded by air on all sides with the only exception of that portion of it which is covered by the brake blocks. This means that the heat transfer from the wheel tyre to the centre is assumed to be carried out by convection and not by conduction. The difference between this assumption and the actual conditions may, however, be neglected since the area of the tyre is very much greater than the area of cross-section between tyre and wheel centre and also since at higher speeds the wheel is subjected to effective « ventilation ».

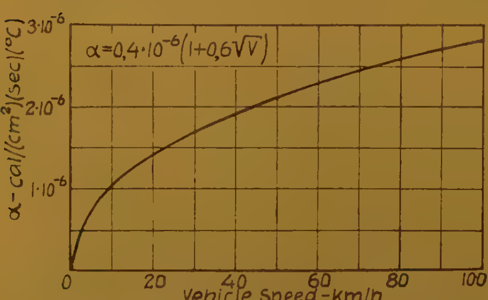


Fig. 18. — Heat transfer co-efficient.

The total amount of heat generated by friction amounts to:

$$Q = Q_b + Q_w \quad . \quad . \quad . \quad (8)$$

where

Q_b = heat quantity at brake block [cal];

Q_w = heat quantity at wheel tyre [cal].

The amount of heat retained by both brake block and wheel tyre amounts to:

$$dQ_1 = Wcdt \quad . \quad . \quad . \quad . \quad (9)$$

where

W = weight of the components concerned [kgr.];

c = specific heat of the material [Kcal/(kgr.) (° C.)];

dt = temperature rise [° C.].

The amount of heat dissipated to the surrounding air will be :

$$dQ_2 = \alpha A(t_1 - t_2)dT = \alpha AtdT \quad . (10)$$

where

α = coefficient of heat transfer [cal/(cm²)(sec.)(° C.)];

A = heat dissipating area [cm²];

t_1 = surface temperature [° C.];

t_2 = air temperature [° C.];

$t = t_1 - t_2$ = temperature difference [° C.].

In accordance with the law of conservation of energy we have :

$$QdT = Wcdt + \alpha AtdT \quad . (11)$$

For the brake block alone we can write :

$$W_b c dt_b = (Q_b - \alpha A_b t_b)dT \quad . (12)$$

and

$$\frac{dt_b}{Q_b - \alpha A_b t_b} = \frac{dT}{W_b c} \quad . \; . (13)$$

To integrate this equation we introduce

$$z = Q_b - \alpha A_b t_b \quad . \; . \; . (14)$$

Solving for t_b

$$t_b = \frac{Q_b - z}{\alpha A_b} \quad . \; . \; . (15)$$

and differentiating we obtain :

$$dt_b = -\frac{dz}{\alpha A_b} \quad . \; . (16)$$

Substituting in equation (13) the relevant values from (15) and (16) we can integrate :

$$-\int \frac{dz}{\alpha A_b z} = \int \frac{dT}{W_b c}$$

$$\frac{-1}{\alpha A_b} lnz = \frac{T}{W_b c} + C$$

Substituting for z its value from equation (14) and representing the constant C in logarithmic form more convenient for subsequent determination :

$$-ln(Q_b - \alpha A_b t_b) = \frac{\alpha A_b T}{W_b c} + lnC \quad (17)$$

To determine the value of C we have to consider the conditions at the beginning of braking, i.e. T = 0, whilst the brake block temperature will be the same as that of the surrounding air. Since both these conditions signify the point of origin we can introduce in equation (17) $t = 0$ and $T = 0$, so that

$$ln(Q_b - 0) = 0 + lnC$$

Consequently

$$lnQ_b = lnC$$

or

$$Q_b = C$$

Introducing the value for C in equation (17) we have

$$ln(Q_b - \alpha A_b t_b) = -\frac{\alpha A_b T}{W_b c} + lnQ_b$$

and :

$$ln\frac{Q_b - \alpha A_b t_b}{Q_b} = -\frac{\alpha A_b T}{W_b c}$$

so that :

$$Q_b - \alpha A_b t_b = Q_b e^{\frac{\alpha A}{W_b c}T}$$

and

$$t_b = \frac{Q_b}{\alpha A_b}\left(1 - e^{-\frac{\alpha A_b}{W_b c}T}\right) \quad . \; . (18)$$

The above equation thus enables the determination of the difference between the brake block and air temperatures as a function of the brake application time T.

The equation for the relevant wheel tyre temperature difference t_w is similar.

It will be noted from equation (18) that all components are easily determined with the exception of the amount of heat Q_b and Q_w to be dealt with.

It is obvious that as the time T, during which the vehicles roll downhill with the brakes applied, increases, the value of e in equation (18) will approach zero, or to put it differently; with increasing T the values of t_b and t_w approach the finite values of $\frac{Q_b}{\alpha A_b}$ and $\frac{Q_w}{\alpha A_w}$ respectively.

The results of rig and road tests have indicated that generally the temperatures experienced by the brake blocks are some three times higher than those recorded at the wheel rim, i.e.

$$t_b = 3t_w \quad . \quad . \quad . \quad . \quad (19)$$

Since

$$Q_w = Q - Q_b$$

we have :

$$t_b = \frac{Q_b}{\alpha A_b} \quad \text{and} \quad t_w = \frac{Q - Q_b}{\alpha A_w}$$

On the basis of equation (19) we can write :

$$\frac{Q_b}{\alpha A_b} = 3\,\frac{Q - Q_b}{\alpha A_w} = 3\,\frac{Q}{\alpha A_w} - 3\,\frac{Q_b}{\alpha A_w}$$

and consequently :

$$Q_b\left(1 + 3\frac{A_b}{A_w}\right) = 3Q\frac{A_b}{A_w}$$

or :

$$Q_b = \frac{3QA_b}{A_w\left(1 + 3\frac{A_b}{A_w}\right)} = Q\,\frac{3A_b}{A_w + 3A_b} \quad . \quad (20)$$

and similarly

$$Q_w = Q\left(1 - \frac{3A_b}{A_w + 3A_b}\right) = Q\,\frac{A_w}{A_w + 3A_b} \quad (21)$$

Assuming that heat at the wheels and brake blocks is generated purely by friction, i.e. neglecting the heat developed due to passing over rail joints, wheel creep and sliding, the amount of heat to be dealt with will be given by the expression :

$$Q = \frac{1}{427}\,\mu \cdot A_b \cdot p \cdot v \quad [\text{cal/sec.}]. \quad (22)$$

where v = vehicle speed [m./sec.],

or :

$$Q = 0.00065 V \mu p A_b \,[\text{cal/sec.}] \quad (23)$$

where V = vehicle speed [km./h.].

Distributing the value of Q between the brake blocks and wheel tyre in accordance with equations (20) and (21) we obtain :

$$Q_b = 0.00195 V \mu p A_b \frac{A_b}{A_w + 3A_b} \quad (24)$$

$$Q_w = 0.00065 V \mu\, p A_b \frac{A_w}{A_w + 3A_b} \quad . \quad (25)$$

Introducing these values in equation (18) and the corresponding equation for t_w we have :

$$t_b = \frac{0.00195 \cdot V \cdot \mu \cdot p \cdot A_b}{\alpha(A_w + 3A_b)}\left(1 - e^{-\frac{\alpha A_b}{W_b c}T}\right) \quad (26)$$

$$t_w = \frac{0.00065 \cdot V \cdot \mu \cdot p \cdot A_b}{\alpha(A_w + 3A_b)}\left(1 - e^{-\frac{\alpha A_w}{W_{wc}}T}\right) \quad (27)$$

where the value of α can be determined with the help of equation (28)

$$\alpha = 0.4 \cdot 10^{-6}(1 + 0.6\sqrt{V}) \quad [\text{cal/(cm}^2\text{)(sec.)(° C.)}] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

The resultant values of the coefficient of heat transfer α are plotted against vehicle speed in Fig. 18. The mean value for specific heat of steel and cast iron is in the following taken as 0.11 Kcal/(kgr.) (° C.).

It will be noted from the structure of equation (18) that the designer can, to a certain extent, influence the ultimate t values by a judicious choice of the A and W values.

With the cars concerned the area and weight of each wheel tyre amounts to $A_w = 11\,200$ cm² and $W_w = 105$ kgr., that of each brake block $A_b = 625$ cm² and $W_b = 6.2$ kgr. In the case of the brake block the value of A_b does not include the portion of the block pressed against the wheel. For these values, and bearing in mind that the temperature difference of the wheel is here caused by the action of two brake blocks, equations (26) and (27) can be written as :

$$t_b = 0.13 \cdot 10^{-6} \cdot \alpha^{-1} \cdot V \cdot \mu \cdot A_b \cdot p \left(1 - e^{-916\alpha T}\right) \quad \ldots \quad (26a)$$

$$t_w = 0.0433 \cdot 10^{-6} \cdot \alpha^{-1} \cdot V \cdot \mu \cdot 2A_b \cdot p \left(1 - e^{-995\alpha T}\right) \quad \ldots \quad (27a)$$

However, it is not necessary to use both equations since in accordance with the previously made assumption $t_b = 3t_w$, whilst according to equation (26) and (27) the heat quantities are distributed as follows :

$$\frac{Q_b}{Q_w} = \frac{0.00195}{0.00065} \cdot \frac{A_b}{A_w} = 3 \cdot \frac{A_b}{A_w}$$

For the present case :

$$\frac{Q_b}{Q_w} = \frac{3\,625}{11\,200} = 0.167$$

so that

$$Q_b \approx 0.17 Q_w$$

Since :

$$Q = Q_b + Q_w$$

or

$$Q = Q_w + 0.17 Q_w$$

we have

$$Q_w = 0.855 Q$$

i.e. 85.5 % of the total heat developed by brake block friction will be absorbed by the tyre.

In the case of a 41 ton two car train descending an incline of 1 in 25 at a steady speed of 10 km./h. a retarding force of 1 555 kgr. will be required to maintain the requisite speed, as compared with a retarding force of 1 455 kgr. required to maintain a downhill speed of 50 km./h. For these values, equations (26*a*) and (27*a*) will read respectively :

$$t_b = 0.13 \cdot 10 \cdot 0.37 \cdot 48.6 \left(1 - e^{-0.00092T}\right)$$

$$t_w = 0.0433 \cdot 10 \cdot 0.37 \cdot 97.2 \left(1 - e^{-0.001T}\right)$$

and

$$t_b = 0.065 \cdot 50 \cdot 0.23 \cdot 45.5 \left(1 - e^{-0.00184T}\right)$$

$$t_w = 0.0216 \cdot 50 \cdot 0.23 \cdot 91 \left(1 - e^{-0.002T}\right)$$

For T reaching values of over 1 hour or so the value of e approaches zero. For this case we have $t_b = 23.4°$ C. and $t_w = 7.8°$ C. for a speed of 10 km./h., and $t_b = 34°$ C. and $t_w = 11.3°$ C. for $V = 50$ km./h. The temperatures thus estimated are representative of the mean values. Much higher temperatures are encountered at the actual contact surfaces.

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[625 .174]

Heating of points during snowy weather,

by

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(Revue Générale des Chemins de fer, August 1947.)

The disturbance created in the running of trains by points becoming blocked with snow, especially when such points are operated at a distance from a signal box, are too well known for it to be necessary to emphasise the importance of keeping them clean during snowy weather. In the larger stations, the considerable number of points and crossings met with and requiring to be kept clear of snow necessitates the stationing, immediately the first flakes begin to fall, of a numerous staff, whose duties are laid down in a programme carefully prepared in advance. A sudden, heavy fall of snow, such as that which occurred in the Paris district on the night of February 28th to March 1st 1946 showed very forcibly the serious nature of the consequences which could result from even a small delay in sending out the clearing parties (1).

The obligation to keep the clearing staff on the ground throughout the period when snow is either falling or threatening to fall entails heavy expense. It is natural therefore to try and see whether it is possible to find some means of heating points as a preventative measure, using some automatic device easy to apply and keep in service as soon as snow appears likely to fall.

The heat required for its working can be obtained from electric or steam heaters.

Electric heating.

1. *By Joule effect.* — The idea of using electric heating on this principle is not new. A first trial of it was made on the Italian Railways at Milan Central Station during the winter of 1932-33, with resistance heater elements and in 1934 was extended to cover 439 points : 249 simple points, 164 double-slips and 26 single-slips; a total of 1 206 sets of points, with a corresponding number of heaters. The cost of installation (1) amounted at that time to 1 200 000 lira (general and supervisory expenses excluded).

The power of each heater was 1 100 watts, equal to a current of 20 amperes at 55 volts.

The German State Railways also interested themselves in the electric heating of points, and after numerous trials, produced shortly before the last war a design of resistance heater differing from the Italian one, and applied it to a number of points, notably in stations in mountain districts subject to heavy falls of snow (2).

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(1) The snow, which continued to fall throughout the night, was 40 to 50 cm. (1′3¾″ to 1′8″) deep in the morning of March 1st. Delays to main line trains, both arriving and departing, of 2 to 3 hours, were experienced in all Paris stations. The suburban traffic was considerably reduced, and could only be resumed as regards Paris-Est station from 5.30 p.m. onwards with but three trains in each direction.

(1) See *Revue Générale des Chemins de fer*, June 1936, p. 453.

(2) See *Revue Générale des Chemins de fer*, April 1939, p. 330.

a) Taking the equipment applied at Milan station as a guide and the fact that electric heating did not involve any essential modification in the design of points and could, on the contrary, be applied to the various ones in service without affecting detrimentally their mechanical characteristics, we made a trial in 1937 of a set of electric heater elements on a double-slip at Belfort sta-

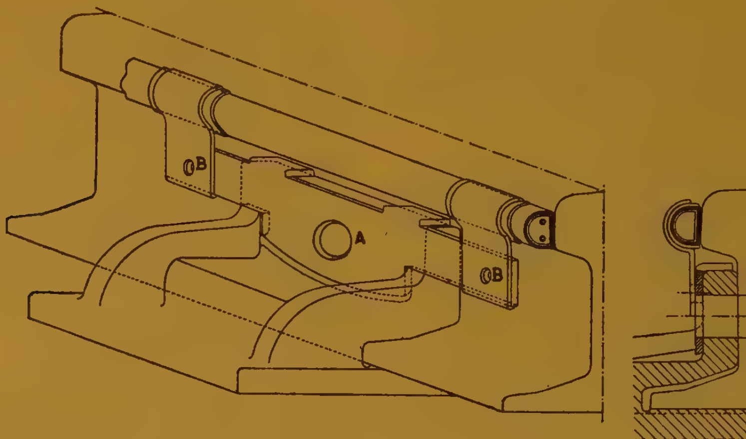


Fig. 1. — Twin elastic clip for fixi ng tubular resistance type heater to 46 kgr. (92 lbs./yard) rail.

This twin clip is formed of a central metal support A and two spring holders B for securing the elements.

— *Only* the central support A is fixed by the permanent way staff.

— The spring holders are put in position by a member of the signal department staff who is required to make sure that the element is in perfect contact with the rail without being held so tightly as to become damaged. A spacer of Klingeritt, 50 mm. ($1^{31}/_{32}''$) wide and 3 mm. ($^{1}/_{8}''$) thick is interposed between the holder B and the heater element.

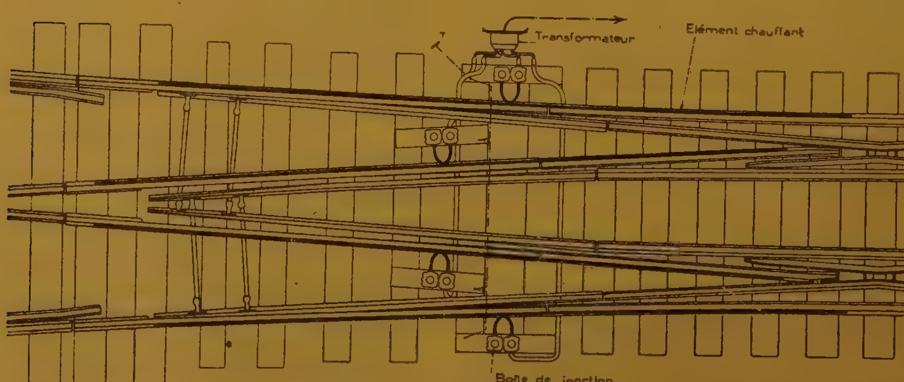


Fig. 2. — General arrangement of double pair of points fitted with resistance type heaters (old system).

tion (¹) (Points Nos. 229-230). The installation, which was entirely destroyed by the bombardments of 1944, comprised 2 resistances on each point tongue, encased in a bronze tube 4 m. (13′1½″) long. The resistance wire, formed in hairpin shape, was insulated from the body of the tube by blocks of steatite, packed with powdered magnesium crystals. The tubes, of semi-circular section, rested with their plane surface against the outer face of the head of the stock rail. Clips suitably spaced, served to hold the tube fast to the rail (Fig. 1).

The general arrangement of the equipment for a double-slip comprised 16 heater elements controlled by a switch placed near No. 2 signal box and fed through armoured cables laid underground from a 24 kVA. transformer reducing the voltage from 200 to 55 volts, with regulating tappings. Each heater element absorbed 1 280 watts when hot. Fig. 2 gives a general view of a set of two points fitted with the heaters.

The graph (Fig. 3) gives the results obtained in the course of a trial on December 16th, 1937, with voltages at the heater terminals of 35, 52 and 62 volts.

The mean power absorbed by an ordinary pair of points (2 heater elements) was high (2.5 kW.) from the fact of the necessity of fixing the elements on the outer face of the stock-rail, which occasioned much loss, any heat insulation on the outer part of the cylinder having been found to be impracticable.

b) In order to reduce such losses and increase the efficiency of the apparatus, we endeavoured to produce an arrangement in which the heat was created directly between the tongue and the stock rail.

The heater elements (²) are formed of a small diametre tube (11 mm. [⁷/₁₆″]) in stainless steel, inside which is a ferro-nickel resistance wire, insulated by a packing of powdered magnesium crystals. Each tube is secured by means of clamping pieces to the lower part of the web of the stock-rail, on the gauge side. The equipment comprises, for an ordinary pair of points, 2 tubes connected electrically in series (Fig. 4).

The trials were made on point No. 76¹ at the Est station Paris, and Nos. 87, 88

(¹) See *Revue Générale des Chemins de fer*, January 1939, p. 51.

(²) Makers : Société Electro-Nickel.

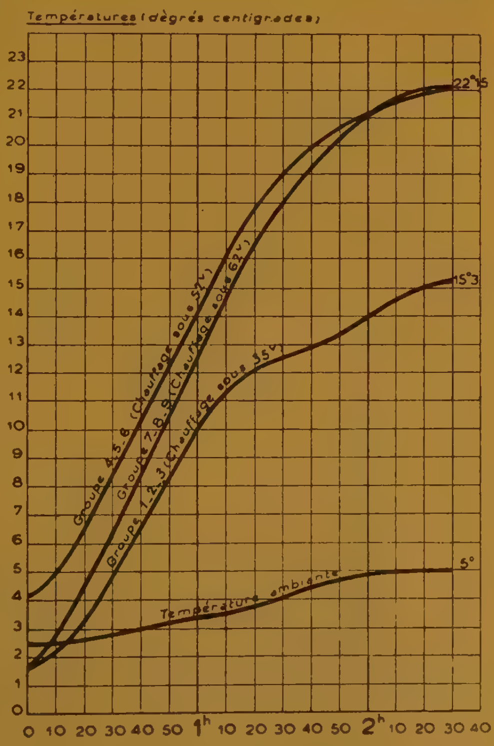


Fig. 3. — Electric heating (old system). Test on December 16th, 1937.

Explanation of French terms :

Températures (degrés centigrades) = temperature in degrees centigrade.
Groupe 4-5-6 (chauffage sous 52 V.) = group 4, 5, 6 (heating at 52 V.).
Groupe 7-8-9 (chauffage sous 62 V.) = group 7, 8, 9 (heating at 62 V.).
Groupe 1-2-3 (chauffage sous 35 V.) = group 1, 2, 3 (heating at 35 V.).
Température ambiante = ambient temperature.

and 90 at Mulhouse Town Station. At the former, the elements are 4 m. (13′ 1½″) long and at the latter 2.80 m.

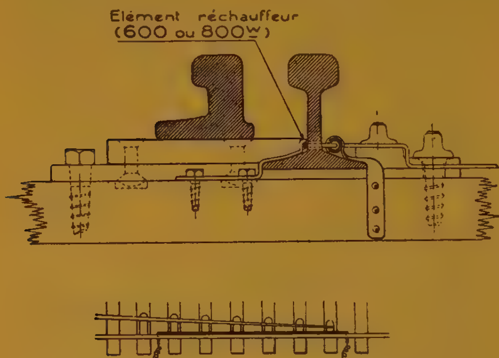


Fig. 4. — Electric resistance heating (new system).

Elément réchauffeur = heating element.

(9′2¼″) by reason of the difference in the type of points.

b_1) The nominal power of each element is either 800 or 600 watts. At Parist-Est, with a primary voltage of 213 and a secondary voltage of 53 at the transformer, with absorbed primary input of 7.03 amperes, the total power absorbed being 1 475 watts, or a power factor cos φ = 0.98.

The temperature of the tubes was found to be about 70°. The graph (Fig. 5) gives the temperature figures measured in the course of the trials.

During the snowfalls of January 31st, 1947, with the heater equipment not in service, we were unable to find out what the results would be, but the effectiveness of the arrangement could be

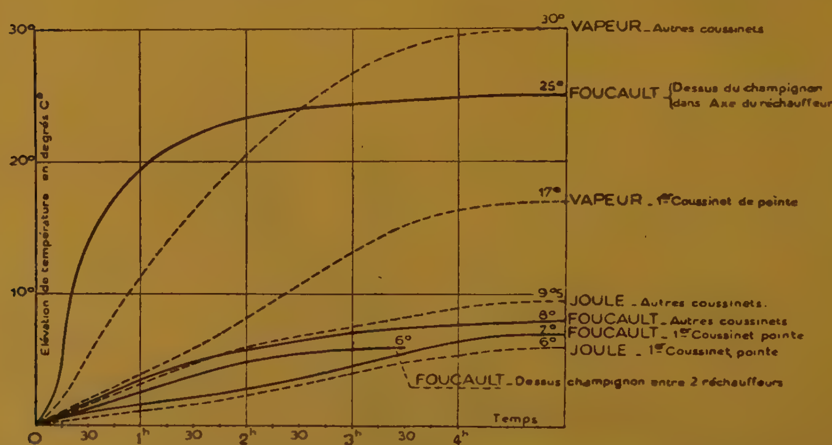


Fig. 5. — New heating systems. Test made in February 1947. Value of heating attained as a function of the time.

Explanation of French terms:

Elévation de température en degrés C. = value of temperature in degrees C.
VAPEUR. — Autres coussinets = STEAM. — Remaining chairs.
FOUCAULT. — Dessus du champignon dans axe du réchauffeur = FOUCAULT, above the rail head on centre line of heater.
VAPEUR. — 1er coussinet de pointe = STEAM, first point chair.
JOULE. — Autres coussinets = JOULE, remaining chairs.
FOUCAULT. — Autres coussinets = FOUCAULT, remaining chairs.
FOUCAULT. — 1er coussinet pointe = FOUCAULT, first point chair.
JOULE. — 1er coussinet pointe = JOULE, first point chair.
FOUCAULT. — Dessus champignon entre 2 réchauffeurs = FOUCAULT, above the rail head between two heaters.
Temps = time.

judged during the less heavy snowfalls which occurred in February.

b_2) At Mulhouse, on the other hand, where the working of the apparatus was able to be tested during a rather heavy fall on February 7th, 1947, the following values were obtained :

Points No.	90	87	88
Power of heater tubes	2 × 600 W.	2 × 800 W.	1 × 600 W. + 1 × 800 W.
Voltage at terminal of the equipment	27.2 volts	26.4 volts	28 volts
Current taken	44 amperes	59 amperes	46 amperes
Power absorbed	1 197 watts	1 558 watts	1 288 watts

The temperature figures taken on the stock-rail are given in the following graphs (Fig. 6).

Examination of these shows that the heating reaches a figure from about 9° to 10° C. above that of the surroundings after about 6 hours and then maintains itself at that figure. This figure, although small, is enough to give good results, as the photograph in Fig. 7 shows.

It has been proved by very numerous observations that the temperatures at which the snow habitually falls are in the region of 0° C. (32° F.) and positive. No technical difficulty would stand in the way of raising the nominal power of the heating elements without increasing their external dimensions, if a higher heating value should be required.

II. *By Foucault currents.* — Each heating element [1] is made up of a laminated magnetic core of U form, and of 36 cm² (5.580 sq. in.) rectangular cross-section, 45 cm. (1′5 11/16″) long, on which is a winding traversed by a 50 cycle alternating current. The two free ends of the U of the magnetic circuit, formed perfectly true, are applied to the web of the rail and the magnetic field so set up completes itself in the rail and gives rise there to Foucault currents which quickly cause its temperature to rise. The investigations of FOURIER on thermic conductibility and those of BIOT and LAMBERT, have shown that when the balance is reached between the heat produced and that lost to the surroundings the heating effect is an exponential function of the distance :

$$T - T_A = (T_0 - T_A)e^{-\alpha x}$$

T is the temperature at a point on the abscissa x;

T_A is the ambient temperature;

T_0 is the temperature set up on the centre line of the heating element;

α is a coefficient dependent on the nature and form of the body or object; in particular for a 46 kgr. rail we have found $\alpha = 0.0033$ for x, valued in mm.

The feed voltage at the winding of each element is 110 or 220, according to the rate of heating up it is desired to obtain.

Eight heaters spaced 1 300 m. (4 265′ 1″) centre to centre, were installed on points No. 45[1], 4 on each stock-rail (Fig. 8). The temperature figure on the centre line of each heater, after the ba-

[1] Made by the « Société Générale d'Applications Electro-thermiques ».

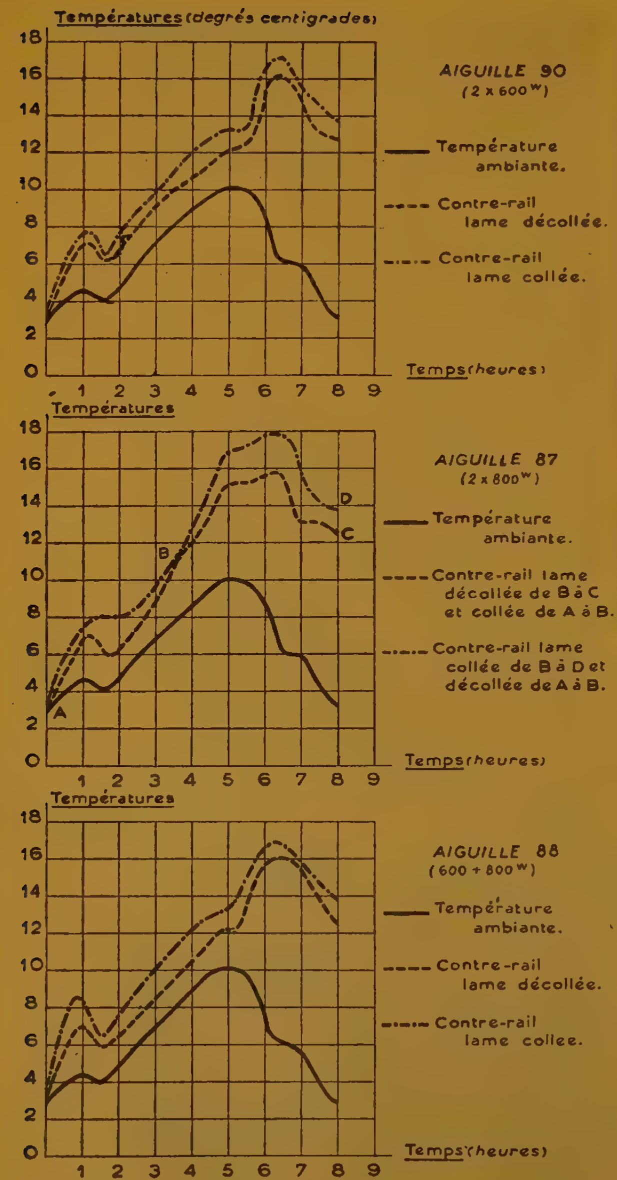


Fig. 6. — Electric resistance heating (new system).

Explanation of French terms:

Aiguille = point.
Température ambiante = ambient temperature.
Contre-rail, lame décollée = stock rail, point open.
Contre-rail, lame collée = stock rail, point closed.
Temps (heures) = time (in hours).
Contre-rail, lame décollée de B à C et collée de A à B = stock rail, point open from B to C and closed from A to B.
Contre-rail, lame collée de B à D et décollée de A à B = stock rail, closed from B to D and open from A to B.

Fig. 7. — Resistance heating (Joule effect).

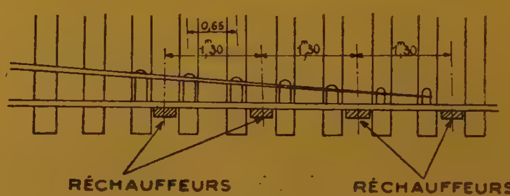


Fig. 8.
Réchauffeurs = heaters.

lance is reached (graph in Fig. 5), is given by:

$$T_0 - T_A = 25°$$

Between two heaters set at 1 300 m., the heat due to each one will be, by the formula cited above:

$$T - T_A = 25e^{-0.0033 \times 650}$$

$\log (T - T_A) = \log 25 - 0.0033 \times 650 \log e = 1.39794 - 0.0033 \times 650 \times 0.43429 = 0.46639$

whence

$$T - T_A = 2°9$$

The effects of the two heaters, situated on each side of the section in question, add themselves to this and the final total upper range of rail temperature on the section will be about 5°8, which is much the same as the experimental result (graph, Fig. 5).

The heaters were connected in half groups across each of the phases of a two phase supply. Current consumption figures came out as follows :

	W (watts)	U (volts)	I (amperes)	$\cos \varphi = \frac{W}{UI}$
Phase 1 .	843.75	108	13 2	0.59
Phase 2 .	825	107	13 2	0.58

This gives a total power consumption of 1 668.75 watts.

Under a voltage of 213 the heaters absorbed a total power of 3 680 watts at 29.5 amperes, a cos value of 0.58.

At the time of the snowfalls of 31st January, 1947, the heaters were put under power at 7 a.m. as soon as the first flakes were seen. No trace of snow or ice remained on the chairs, although the thickness on those points which were not kept clear by cleaning was of the order of 15 cm. (6″) and the points were neither cleaned nor served with paraffin (Fig. 9).

Fig. 9. — Heating by Foucault currents.

Fig. 10. — Condition of points not fitted with heaters.

In Fig. 10 is seen, in comparison, a pair of non-heated points.

Steam heating.

When in 1937 tests with heaters were being carried out at Belfort station, a trial was made with a steam heater at the same time as the electric type were being tested.

Two double slip switches (points Nos. 238/239 and 253/254) were so equipped and in 1941 steam heating was extended to points Nos. 259/260, 225/226 and 217/218.

Like the electric heaters, the steam heaters were completely destroyed in the 1944 bombardments.

The heating elements were formed of steel tubes 15 × 21 flattened on the side next to the outer face of the head of the rail to which they were attached (Fig. 11).

The steam was provided by a V 600 type locomotive stationed near the site in a dead-end road nearby. Steel tube runs, placed in a conduit between tracks, were connected to the locomotive and the heater elements by flexible tubing. A system of stop-cocks operated by the locomotive fireman allowed the admission of steam to the piping runs to be controlled.

steam being regulated and brought down to a pressure of 50 gr., at which the hourly consumption of steam amounts to about 5 kgr.

During the snowfalls of 31st January, 1947, these heaters not only got rid of all the snow from the chairs but also by radiation from the track and sleepers.

The temperature figures are given by the graph in Fig. 5.

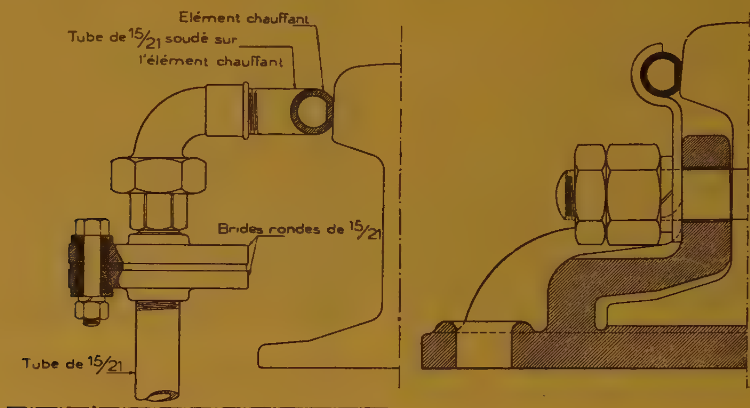


Fig. 11. — Steam heating.

Explanation of French terms:

Elément chauffant = heating element.
Tube de 15/21 soudé sur l'élément chauffant = 15/21 tube welded to heater element.
Brides rondes de 15/21 = round 15/21 flanges.
Tube de 15/21 = 15/21 tube.

Pressure, as shown on the locomotive steam gauge, was required to be between 4.5 and 6 kgr.

In 1946, we took up trials again, with equipment practically the same as that used at Belfort, at Paris-Est Station.

The heater used is formed of two iron tubes, 27 mm. ($1^1/_{16}''$) outside diameter, and 9.80 m. ($32'1^7/_8''$) long, placed alongside each stock rail and attached with their flattened faces against the outside of it. The two tubes are connected together at each end and branched in parallel on a high pressure steam pipe run. A cock placed on the spot in the feed pipe to the tubes allows of the

Comparison between results obtained.

a) The steam heating device, by reason of the greater heating power obtained, is the most efficacious, as Fig. 12 shows, but possesses serious disadvantages :

(1) Blockage of the pipe runs by the freezing of the condensed water which appears when the apparatus is put out of use, in spite of the fact that this was obviated as much as possible by putting the drain cocks at the lowest parts of the pipe runs and heat insulating the latter wherever it could be done. The operation of the drain cocks, when putting the equipment in and out of service

was a long operation where there were many sets of points fitted with steam heaters.

(2) Complicated nature of the installation (pipe runs, cocks, etc.) when extending it generally over a number of points, by reason of the appreciable distances separating them from the spot where the steam is generated. Operation and adjustment of the stop cocks and drain cocks takes a long time and requires much care.

Fig. 12. — Steam heating.

(3) Rapid deterioration from oxidation of the tubes, attachments and runs, leading to constant and heavy maintenance.

(4) System rendered inoperative in the case where the source of steam breaks down, resulting inevitably in freezing of the pipe runs.

b) The two electric devices give substantially the same results. However the power absorbed by the one working by Foucault currents (1 670 watts) is slightly greater than that of the heaters using the Joule effect (1 475 watts) and the power factor of the first type (0.58) is lower than that of the second (0.98).

The heaters working by induction would have the advantage of being able to be taken down easily for inspection and stocking at the end of winter and refixing at the approach of the cold weather. The expense of so doing would be compensated by saving in maintenance charges.

The resistance tube heaters would be more delicate to remove and it would be preferable to leave them in place all the time. Their maintenance too would be reduced if they were to be made of stainless steel, a possibility in the future. These devices, less expensive than the induction heaters, take up less room and are more easily applied to points. The closing off of the inlets and outlets to the tubes would need to be improved by using a special cement having a coefficient of expansion equal to that of the metal of which the tubes are made, in order to avoid all chance of moisture getting back into them.

As these resistance elements are capable of being fed at very low voltage, it will always be possible to choose the voltage desired, so that no defect in the insulation can bring about an irregularity in the working of the track circuit.

Conclusion.

The steam system is not suitable for adoption for the reasons stated.

The electric systems, susceptible of improvement from the point of view of insulation and the quality of the materials, are alone acceptable and are capable of giving every satisfaction.

The levels of temperature reached on the chairs are of the order of 6 to 9° C. (42.8° to 48.2° F.) and seem to be sufficient, while they are capable of being modified easily by altering the internal resistance of the heating elements.

As a guide, it may be mentioned that the application of electric heating to the 125 pairs of points essential to the working of Paris Est Station would involve a

total load of 200 kW. (204 kVA. for the Joule type heaters and 340 kVA. for those operating by Foucault currents).

Examination of the effect of the alternating current on the working of the track circuiting.

1. Laboratory tests.

These tests involved :

a) a standard 2 Ω 2 Ω track relay ;

b) an Est type 2 Ω 2 Ω track relay.

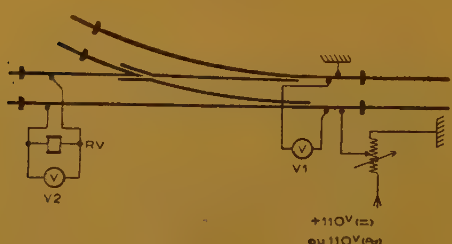
By connecting up on the potentiometer principle the minimum alternating voltage which would just cause the relay to close its front contacts was ascertained. The figures given correspond to a voltage gradually increased from 0 up to the pick-up value.

The minimum alternating voltages 50 P/s at which the relay closes its contacts were found to be :

for the Est type (4 Ω) track relay 44 volts,

for the standard type (4Ω) track relay 45.5 volts.

By reducing this voltage gradually, it was found that the relays opened their contacts at values of about 1 volt less than those given above.

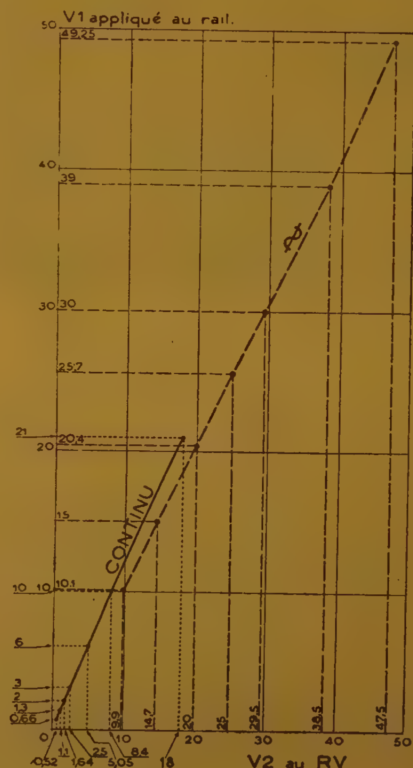


2. Tests on the track.

These tests were carried out on points No. 76[1] in relatively dry weather, the last fall of rain having taken place about 24 hours before. The connections used are shown in the accompanying diagram. The track relay was an Est 2Ω 2Ω type. In order to compare the value of the potential difference at the relay terminals as a function of the voltage applied to the rail, according to the kind of current involved (alternating or direct) two forms of tests were carried out :

a) *Alternating current :*

Voltage applied V1.	Voltage at terminals of track relay V2.
10.1	9.9
15	14.7
20.4	20
25.7	25
30	29.5
39	38.5
49.25	47.5
63	60.25



Explanation of French terms :

V1 appliqué au rail = voltage applied to the rail.

Continu = direct current or D.C.

With 50 volts at the rail a short circuit on the track produced the fall of the relay in the proper manner without any adverse effect.

b) *Direct current :*

Voltage applied V1.	Voltage at terminals of track relay V2.
0.66	0.52
1.3	1.1
2	1.64
3	2.5
6	5.05
10	8.4
21	18

These results have been set forth in the curves on the accompanying diagram, and it appears from them that if, by reason of a double coincidence, the two connections of the feed to the heater resistances situated on each row of rails were to become connected to the body of them, the track relay of the insulated section concerned would be able to become subject to the alternating heater circuit voltage. The protecting fuse in the track relay leads would at once blow, during the brief interval that this alternating voltage was applied, but safety would be assured nevertheless, for even if the relay were to become energised it would drop away when an axle short-circuited the insulated section. For greater safety however, it would be preferable to use a heating voltage of less than 43 volts.

[625 .113]

The Mechanical - Diagram - Corrector,

for calculating new or corrected versed sines and the degree of displacement required for correcting curves,

by L. BIENFAIT,

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(From the *Revue Générale des Chemins de fer*, May-June, 1946.)

For many years, the study of railway curves has occupied engineers and mathematicians, particularly since increases in speed necessitated the introduction of progressive or parabolic transition curves.

However, the alignment, whilst it may be perfect when the line is laid, does not remain so; the forces exerted on the track and inequalities of strength in the sleeper bed and in the rail seat all tend to cause gradual distortion in alignment as well as in track level. These distortions increase the stresses set up by rolling stock and the risk of accident increases.

It is therefore important to ensure a permanently suitable alignment or to remedy the defects as they arise. The method generally adopted for this purpose is to take equidistant versed sines and to calculate the correction which must be made in the distorted curve to bring the versines constant in circular curves or regularly progressive or regressive in transitions.

The various methods, based purely on calculation and comprising the choice a priori *of new regular versines — i.e. constant or progressive — from which, according to the existing versines, the amount of displacement is reckoned, still leave the initial dimensions to be modified if the variations are too great, or impractical owing to fixed points. These modifications are however very delicate and lead only gradually towards the ideal position, which is to have a minimum of displacement throughout the length of the curve, and which one may say is never obtained by straight calculation.*

An easy method without calculation, but one which demands experience and care, is correction by successive approximation from stake to stake, applying simply the initial theorem : a deviation « r » towards the outside at one point of a curve increases the versed sine at this point by an amount « r » and reduces the versed sine at the points on each side by an amount $\frac{r}{2}$.

It was decided to try this method mechanically. Mr. BIENFAIT, Inspector, Nord Region, whose inventive faculties I was able to appreciate when I worked with him on the Organising Commission of the Nord Railways some twelve years ago, set himself to find a solution to the problem.

After years of study, test and trials, he succeeded in creating a small machine which, without having the degree of perfection of some of the latest American mechanical calculators, is portable, easily handled and makes light work of the

fairly involved calculations required in correcting curves by the versed sine method.

The Mechanical-Diagram-Corrector can greatly simplify the regularisation of curves by correction of the versed sines; its use by the whole Permanent Way Department of the French National Railways has just been agreed.

LEDUC,
Ingénieur en Chef au Service technique des Installations fixes de la S.N.C.F.

Verification of the alignment of curves.

In verifying the alignment of curved track, use is made of an elementary geometrical property of circumference, by which arcs subtended by equal chords have equal versines.

The versines obtained are drawn full size at 5 or 10 mm. distances, giving a diagramme which is an exact reproduction of the curve, and which shows accurately any irregularities.

In a perfect curve the versines, which are nil for straight track, increase regularly in progressive transition curves to a constant maximum in the circular arc.

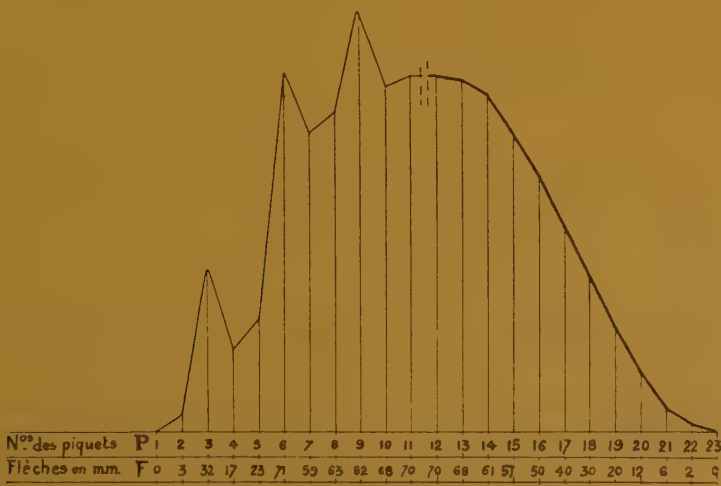


Fig. 1.

Explanation of French terms:
N°s des piquets = No. of the pickets.
Flèches en mm. = versines in mm.

The present method consists in marking one of the rails at equal distances (say 10 metres) and measuring the versed sine at each point from a chord formed by a steel wire stretched between the points on either side of the one whose versine is to be measured.

Figure 1 shows the diagram of a curve, one part of which is of satisfactorily regular alignment and the other part of which is irregular and requires re-alignment.

Correction of curved alignment by calculation.

For fifty years, Permanent Way Engineers have compiled methods of calculation for replacing measured versines by new versines and the corresponding displacement required, so as to correct irregularities in curves by slewing the tracks.

The basis of the methods of calculation is the same elementary principle which can be formulated as follows : *in a curve, it is possible to change the value of a versed sine but the value of the versed sine on each side is by this fact found to be altered by half the amount of the first alteration in an inverse direction.*

(This principle is not absolute, but in curves having such a large radius as has railway track, the generalisation is sufficiently accurate for all practical purposes.)

Fig. 2 shews this principle diagrammatically. If the versine at point 3 is increased by an amount d, the versines at points 2 and 4 are decreased by $\frac{d}{2}$.

The different methods of calculation, all fairly similar, give good results, but

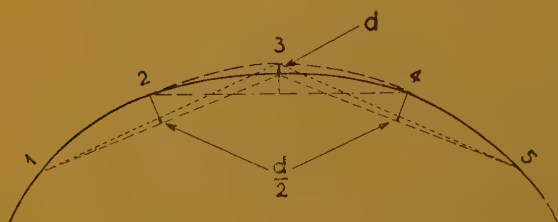


Fig. 2.

contain several complications; they require fairly long calculations from which trial solutions cannot be excluded, and need some experience for correct application.

In brief, the methods provide for the alteration of the measured versines $f1$, $f2$, $f3$... fn, and the calculation of the displacement $d1$, $d2$, $d3$... dn to be applied to points 1, 2, 3... n to give the required new versines F1, F2, F3... Fn.

The mechanical-diagram-corrector (Me-di-co).

The Me-di-co is the mechanical application of the basic principle of the methods of correction represented in Fig. 2.

It provides, in the normal scale and form, a physical representation of the alignment diagram (versines in actual size at 11 mm. distances) and allows a rapid determination, without calculation, of the new versines F and the corresponding displacement d required to replace the measured versines f.

The Me-di-co is therefore a calculating machine and at the same time a mechanical diagram, presenting the method of correction by versines with all the requisite flexibility and even with possibilities which are in practice not obtainable by calculation.

Description and operation.

In the Me-di-co (see diagram, fig. 3) each of the versines obtained on the site is registered by a screwed rod forming a worm gear (1), which is rotated to cause lateral displacement of a small block (2) provided with an indicator (3) which runs in a slot (4) graduated in millimetres (5). Each screwed rod (1) has, grub-screwed to its ends, a 30-toothed gear (6) and a 15-toothed, end-cut, pinion (7).

The gears (6) and (7) are staggered on the successive rods.

The end of each screwed rod which is cut square (8) allows the individual operation of the rod by means of the handle shewn in Fig. 4, rotation of which moves the indicator (3) to give a curve similar to that in Fig. 1.

A second handle (Fig. 5) carries a pinion (9) of the same pitch as the

pinion (6) of each screwed rod, but having only half the number of teeth (15-toothed), the end of the handle (10) engages with the pinion (7) of the rods.

This handle can be placed on the pinion (7) end of each rod, engaging on the end with that pinion and at the sides with the pinions (6) of the neighbouring versines.

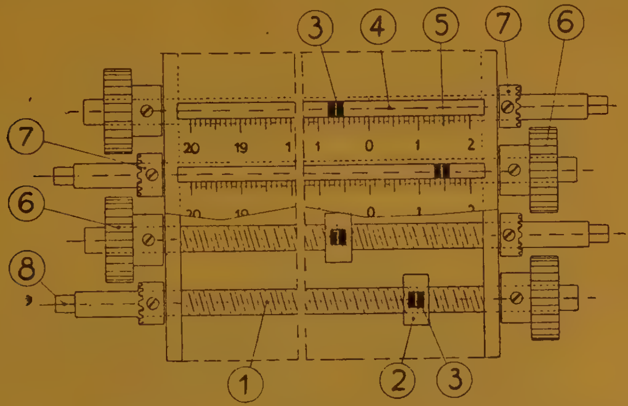


Fig. 3.

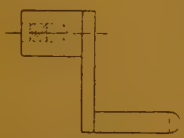


Fig. 4.

By rotating this handle, the indicator on the screwed rod is moved as far as necessary in the desired direction, but the indicator on the two neighbouring rods moves half the same distance in the opposite direction.

The versines originally measured are thus modified as necessary (small ones increased, large ones reduced) by the manipulation of the three versines engaged by the handle with pinion.

By successive improvements to the diagram of the recorded versines, new versines are obtained which give the required diagram.

The Me-di-co also provides, without calculation or additional operations, the corresponding displacement at each point, that is the amount of displacement to be given to the track or to the pickets to give the new versines.

This particularly important function is performed in the following manner :

During the manipulation of the geared handle, the *index* for each versine carries out two kinds of movements :

(1) direct movements; those having a value + or — d of the versine on which it is set by the geared handle;

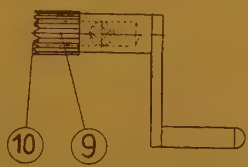


Fig. 5.

(2) indirect movements; those having a value of $\frac{-\,d}{+\,2}$, resulting from the direct movement of one of the two adjacent versines.

The actual displacement from each point is the algebraic sum of the individual direct movements of the index corresponding to this point.

The Me-di-co records and indicates this displacement in the following manner : See Fig. 6 (transverse half-section shewn diagrammatically).

Above each screwed rod (1) at the pinion (7) end, is the revolution counter (11) which, through the pinions (12) and (13) and the geared handle, records the direct movements of the corresponding index (3) effected by this handle alone.

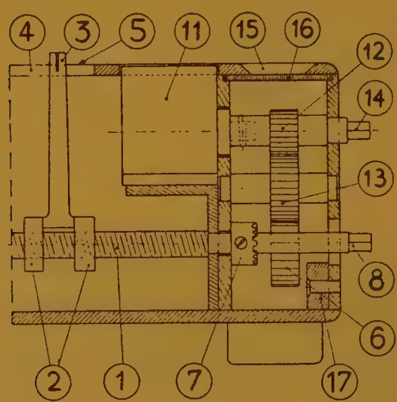


Fig. 6.

The relation between the number of teeth on the pinions also engaged (9), (12), (13) and the pitch of the screwed rod is such that the revolution counter (11) counts one when the indicator (3) has moved 1 mm.

The counter works in both directions, marking 1, 2, 3, etc... positively, and 9999, 9998, 9997, etc... negatively.

Moreover, each counter can be set individually at zero without altering the adjacent versine, by using the handle shewn in fig. 4 on the end of the counter pinion shaft (14).

The Me-di-co has on the top, at the right of each versine on the counter side, a window (15) shewing the number of the corresponding picket which is engraved on a slide (16).

The even numbers are on one side, the odd numbers on the other.

The Me-di-co can comprise any desired number of versines of any length.

The prototype which has been built, comprising 32 versines of 250 mm. (200 mm. positive and 50 mm. negative) has been found very suitable in practice.

It measures 39 cm. (1′3$^3/_8$″) in length, 38 cm. (1′2$^{15}/_{16}$″) in width and is 6 cm. (2$^3/_8$″) deep. The weight is 6 kgr. (13 lbs.). It is quite portable, and a case, with carrying handle, has been provided (Fig. 7).

The 32 versines of 250 mm., as in the prototype, provide for all conditions, since any alignment which has to be dealt with can always be sectioned off by 30 pickets.

Use of the device.

The very simple operation of the Me-di-co is implicit in the description of its manufacture and arrangement detailed in the preceding chapter.

To calculate a re-alignment, it is only necessary to carry out the following operations :

1. — *Set the counter at zero.*

Put the counters at zero successively by rotating, in the required direction, the square-ended shaft of each counter, using the appropriate handle.

2. — *Set out the diagram requiring correction.*

a) set the moveable slides to make the indicator numbers correspond to the picket or track point numbers.

b) move successively, by the required amount, the indicator for each versine, rotating the screwed rods in the appropriate direction by the use of the correct handle on the square end of each rod.

3. — *Correction.*

Carry out the modification in groups of

three successive versines, using the geared handle (reducing excessive versines and increasing small ones).

Facility in operation is easily acquired ; it is sufficient to know how to read the diagram, which can be improved and moulded to suit the manipulator.

4. — *Assessment of results.*

a) the *new versines* are shewn directly by the position of the indicator on each rod, along the corresponding millimetric graduation.

All re-alignments which can be calculated can be dealt with more effectively by the Me-di-co; circular curve, transition, complete curve, improvements wholly or in part, modifications to the alignment, lengthening of the transition curve, coverage of fixed points, compulsory radii, etc.

The employee who can satisfactorily read and understand a diagram, who appreciates the possibilities and accuracy of the method, can rapidly acquire experience and facility in operation of the apparatus.

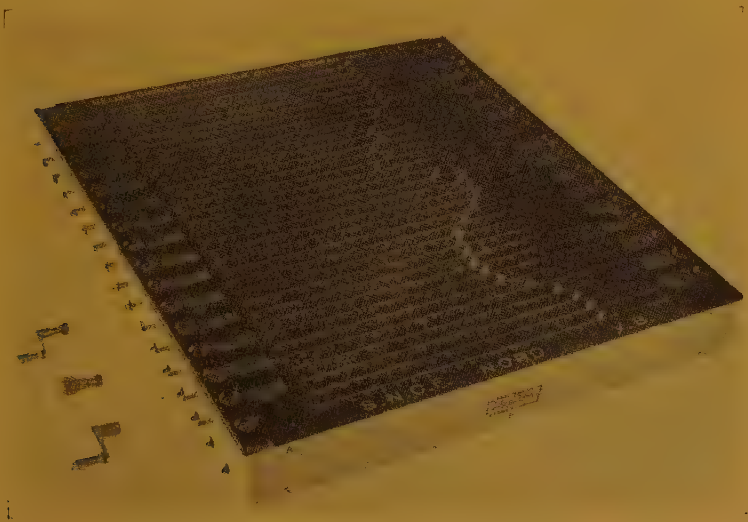


Fig. 7.

b) the *amount of movement* is shewn by the counters for each versine. Negative movement (towards the interior of the curve) is shewn by the figures on the counter.

Example : If a counter shews 0082, the negative movement is 82 mm.

Positive movement (towards the exterior of the curve) is indicated by the figure to be added to obtain 10 000 at the counter figures.

Example : If a counter shews 9932, the positive movement is 68 mm.

It is not necessary for him to know how to correct a curve by calculation to use the Me-di-co.

Fig. 8 shows the state of the apparatus after correction of a curve. The indicators shew the new versines and the counters shew the movement; in addition the original diagram has been superimposed to facilitate comparison.

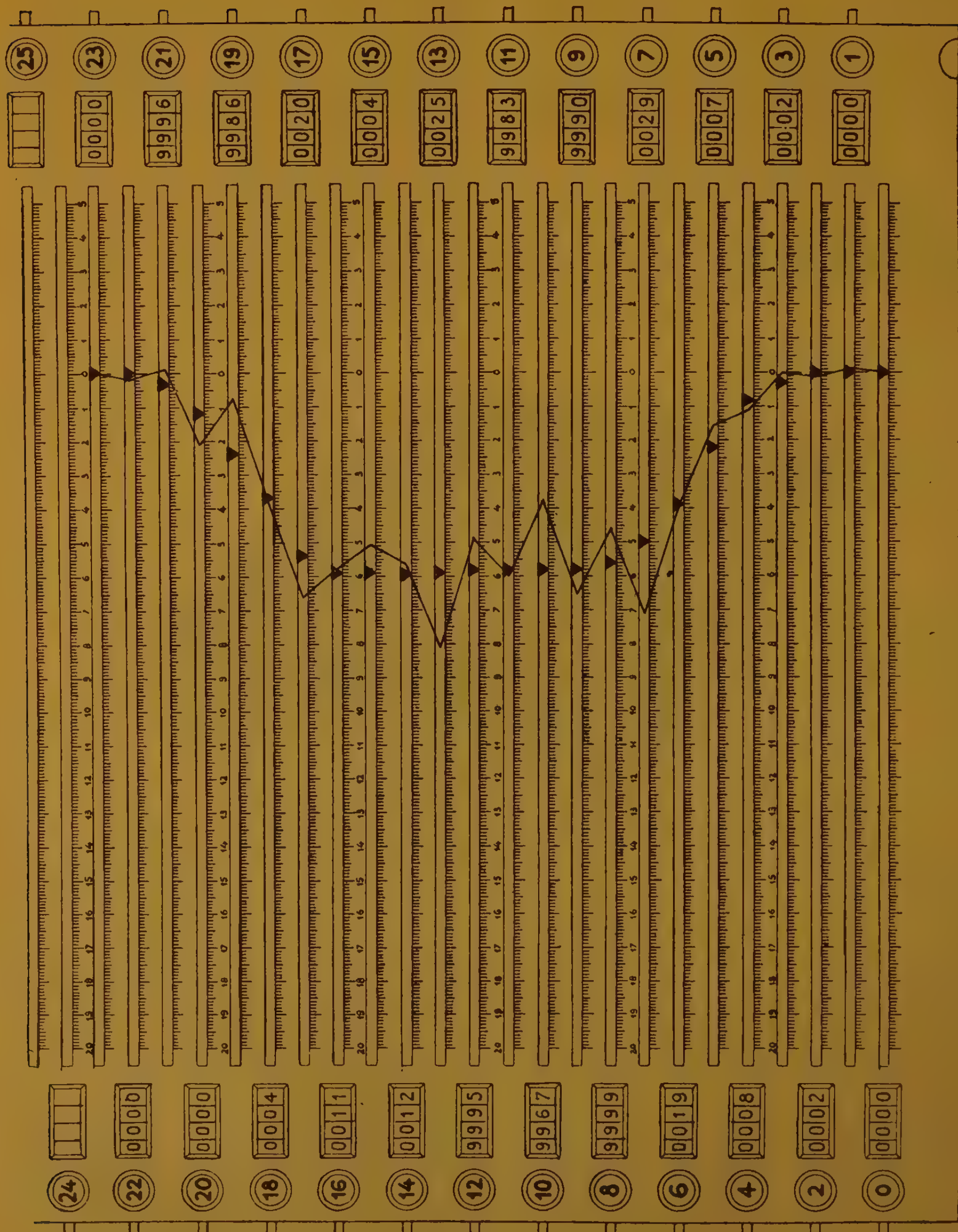
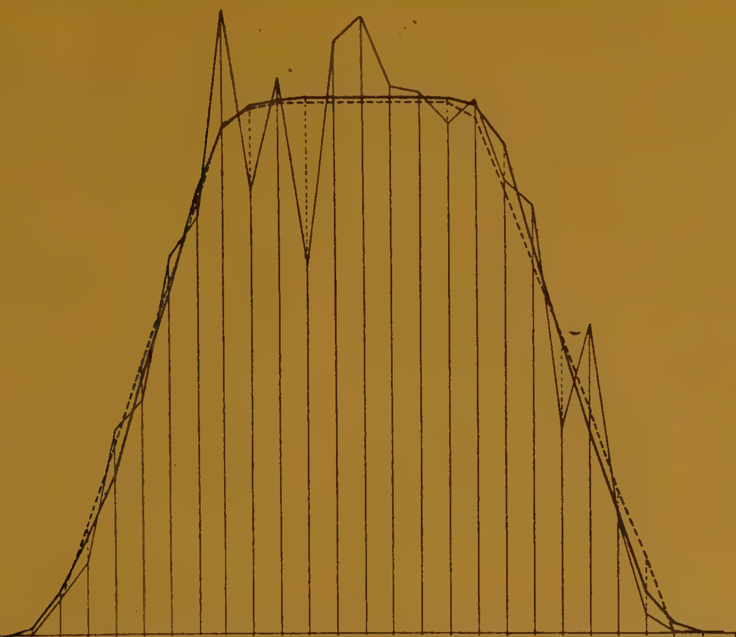


Fig. 8.



N.os des Piquets P	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Flèches relevées f	0	7	14	40	46	74	82	123	87	109	72	116	121	107	106	100	105	89	84	40	61	22	4	0	0
Flèches nouvelles F — Calcul	0	7	21	37	53	69	85	100	103	104	104	104	104	104	104	104	101	87	72	59	44	28	15	0	0
Flèches nouvelles F — Médico	1,5	8,5	19,5	31,5	50,5	68	86,5	99,5	103,5	104,5	105	105	105	104,5	105	105	103,5	96	76	58	39,5	23,5	8	2	0
deplacements d — Calcul	0	0	0	-14	-22	-44	-56	-74	-46	-50	-44	-102	-136	-136	-130	-120	-118	-108	-94	-56	-56	-22	0	0	0
deplacements d — Medico	0	-3	-9	-26	-26	-35	-32	-38	+3	+11	+28	-18	-42	-36	-25	-12	-9	-3	-11	-3	-31	-16	-4	0	0

Fig. 9.

Explanation of French terms:

N.os des piquets P = No. of the pickets P.
Flèches relevées f = Existing versines f.
Flèches nouvelles F = New versines F.
Déplacements d = displacements d.

Advantages.

The Me-di-co has the following important advantages over calculation :

1. — *Complete obviation of calculation.*

As shewn above, the Me-di-co provides new versines F and the amount of displacement *d* from the existing versines *f*.

2. — *Considerable reduction in the time required for correction.*

The Me-di-co reduces by more than 4/5ths. the time required for office work.

Whilst an average of two hours is necessary to calculate a curve marked out with 30 pickets, half an hour with the Me-di-co is sufficient to give a satisfactory solution.

3. — *Considerably less displacement required.*

The Me-di-co provides for the original diagram to be modified progressively to the new alignment by successive im-

provements, limited to three-picket distances.

The displacements are not, as is the case with calculation, affected by arbitrarily fixed versines, nor by the necessity for balancing moments.

The Me-di-co has dealt with diagrams which had already been corrected by existing methods; solutions were obtained by the Me-di-co which were just as good practically as those obtained by calculation with the amount of displacement reduced by 4/5ths. and more.

Fig. 9 gives comparative results for a curve dealt with by calculation in a note on curve correction.

The results obtained are practically identical. The average displacements, however, are 75 mm. ($2^{61}/_{64}''$) by calculation and only 19 mm. ($\frac{3}{4}''$) with the Me-di-co.

The possibility of reducing displacement to an absolute minimum is the most important advantage provided by the Me-di-co. It reflects large economies in labour in setting out corrected curves.

4. — *Permanent indication of the displacement.*

Whilst calculation only shows the amounts of displacement at the conclusion of the corrections, the Me-di-co shews them continuously during the operation.

The counter for each picket gives, in effect, the corresponding displacement permanently.

This result is very important, as it guides the operator and facilitates the determination of minimum displacement, correction through fixed points or compulsory displacement.

5. — *Flexibility in use.*

Its facility and speed in use, the permanent indication of successive diagrams and corresponding displacement give the Me-di-co great flexibility in use.

Whilst calculations are often delicate and long, the Me-di-co is quick, visible and pleasant to use.

Under present practice, an employee works a full day on a special investigation into a 50-picket correction, and selects one of 4 or 5 tentative solutions. The Me-di-co will, in a similar case, give a selected result in less than an hour, chosen from a succession of more or less satisfactory diagrams.

Use of the Me-di-co for new alignments.

The foregoing explanations deal mainly with the use of the Me-di-co for correcting curves, but it can also be used to advantage for new alignments. It is in practice sufficient to stake out equidistant points following the general outline of the desired alignment and deal with this as a curve needing correction. Moreover, as a first step, the versines can be measured in cm. instead of mm., the Me-di-co will then give, in cm., the amount of displacement required at each stake.

NEW BOOKS AND PUBLICATIONS.

[385. (09 (.44)]

L'effort de reconstruction de la S.N.C.F. *(The reconstruction of the French National Railways).* — A brochure ($8\,^1/_4 \times 10\,^5/_8$ in.) of 28 pages and numerous illustrations. — 1946, published by the French National Railways (S.N.C.F.), 88, rue Saint-Lazare, Paris.

This note gives in a few pages a great deal of information about the state of the railway system at the outbreak of war, the situation after the liberation, the re-opening to traffic, and finally the French National Railways' programme of renovation and reconstruction.

Before the war the equipment of the railway was in good state of repair, and was being modernised at a relatively high speed. The train speeds are a very good indication of this. The general limit of 120 km. (75 miles)/h. had been increased to 130 and 140 (80 and 87 miles)/h. on certain lines and for certain trains. The rolling stock, though more than sufficient to meet the traffic requirements of the period, was of various types and rather old. The average age of the steam locomotives and waggons was 28 years, and that of the coaches 24 years. However they were all in an excellent state of repair and the foundations of the system were good and solid. This is proved by the truly remarkable performances achieved during the battle of France.

At the time of the liberation the system was in a truly dreadful state. A few figures will make this clear : 2 603 bridges and viaducts had been destroyed, 45 tunnels blocked, 4 870 km. (3 025 miles) of track destroyed, 14 040 sets of track equipment destroyed or removed. The map showing the bridges that had been destroyed and the sections of line where no traffic could be run is very enlightening.

The re-opening to traffic was carried out remarkably quickly. The author gives the principal stages which were pushed through very rapidly. At the date of publication, nearly the whole of the system (about 40 000 km. = 24 855 miles) was once more in operation, whereas at the beginning the workable lines consisted of a few isolated sections, totalling not more than 18 000 km. (11 184 miles). At the same time the electrical installations were being repaired together with the mechanical equipment of the track.

Impressive figures are given concerning the repairing or rebuilding of passenger and goods stations, as well as of marshalling yards. An exceptional effort was made to rebuild the vital installations in the shops and sheds, so as to give the minimum of room and equipment needed. More than 2 000 machine tools, either new or repaired, to mention only one item, were put back into service.

As for the traction and rolling stock, without counting wear due to well-known causes, this was numerically very insufficient : 3 000 steam locomotives only were in working order out of a total of 17 058 at the outbreak of hostilities, only 172 000 waggons of various origin were usable, whereas in 1939 there were 478 000 waggons; 8 000 coaches and vans could be used compared with 37 700 coaches and vans in 1939. The author gives the measures taken to build up the stock again; the marshalling of all the resources of the French National Railways and private industry to undertake repairs on a priority basis for important periodic maintenance operations and orders placed abroad (in the United States, Canada, and England). On the 15th May 1946, the French National Railways had at their disposal 9 600 steam locomotives, 15 800 coaches and vans, 265 000 waggons and 950 electric locomotives and railcars. Recovery of stock from Germany and the occupied countries had not been very successful up to that time.

The author pays tribute to the devotion of the staff of the French National Railways and private firms who had to work under dreadful conditions. The efforts made are shown by the way important work was carried out in record time, such as the repair of the Villeneuve-Yard double group of lines in 5 days, and the rebuilding of the Maintenon Viaduct in two months, a structure 320 m. (350 yards) long, where 22 arches out of the 32 had been completely destroyed. In nearly all the shops and sheds the men work 54 hours a week.

Graphs show the progress made in the mileage and traffic. We will merely state that the number of tonnes-kilometres for goods traffic is higher now than in 1938. The number of waggons loaded is less, but the average load has been increased from 9 to 12 tonnes and the average distance of the run has increased from 200 km. to 285 km. (124 to 177 miles).

However remarkable the results achieved in the sphere of restoring the lines to traffic and rebuilding the equipment needed immediately, this is however only the first stage of the task with which the Management of the French National Railways is faced. Much of the repair work and rebuilding is only of a temporary character. The final measures have still to be undertaken. This is the subject of the last part of the book which deals with the renovation and reconstitution programme. The French National Railways have wished to profit by an unprecedented chance to carry out a large scale renovation programme in a relatively short time.

The programme covers a period of ten years. It makes provision for the modernisation of the permanent way and signalling, the passenger and goods stations and marshalling yards, the sheds and shops. Development of electrification is to play an exceptional part in this programme. A great effort will be made to have new and standardized steam locomotives. The electric locomotives will be of the most approved types. As far as diesel traction is concerned, trials made before the war make it possible to go on to the industrial stage. Passenger coaches will be lighter and better designed; separate wheels and axles will be replaced by bogies. Three types of railcars only have been retained as the basis of future constructions. Apart from special waggons, the types of waggons will be very few in number.

This bold programme shows the willingness of the Railway to renovate its equipment and its methods in order to contribute as much as it possibly can towards the renaissance of the economic life of the country.

E. M.

[**385**. (09 (.494)]

Le Centenaire des Chemins de fer suisses *(The Centenary of the Swiss Railways)*. — A special issue of the *Bulletin technique de la Suisse romande*. July 12th 1947. — A brochure ($8^3/_4 \times 12^1/_4$ in.) of 48 pages, with numerous illustrations. — 1947, Lausanne, Librairie F. Rouge & Cie.

The Swiss Railways go back to the year 1847. On the 9th August of that year the first Swiss line was inaugurated. This linked up the towns of Zurich and Baden, and was 23.3 kilometres (14.477 miles) long. The Delegates to the 14th Session of the International Railway Congress Association which was held at Lucern at the end of June 1947 were able to admire the remarkable exhibition organised by the Federal Railways in celebration of this anniversary. They were even able to travel in a replica of the historical train of 1847.

The Management of the *Bulletin technique de la Suisse Romande* were well

advised in publishing a special railway number to commemorate this event. They asked the Engineers and Higher Officers of the Federal Railways most qualified to do so, to give reports on their special subjects. These reports as a whole give a very clear picture of the railway system under its most characteristic aspects.

In the introductory note called « The Federal Railways and their Constructions » Mr. Maurice PASCHOUD, General Manager of the Swiss Federal Railways, gave himself the task of showing how the management of the railway has carried out the mission with which it was entrusted and what still remains to be done to meet successfully the competition of road and air transport. The development of this theme gives him the opportunity of insisting upon the most recent innovations reported by other contributors to the *Review*. These have dealt in turn with the following subjects : bridges, the permanent way, signalling and safety equipment, Lausanne-Sebeillon Station, the light weight rolling stock of the Federal Railways, certain electrical installations, and the timetables.

It is very inspiring to read these notes. They make it possible to appreciate the pioneer spirit of the technicians of the Swiss Federal Railways.

As it is not possible to give a complete analysis of the book, we must limit ourselves to a few remarks. In the article on *bridges*, which is beautifully illustrated, amongst recent constructions, the Lorraine to Berne Viaduct is dealt with, a reinforced concrete structure 1 100 m. (1 202 yards) long with a 150 m. (164 yards) span over the Aar, the largest four track railway bridge in Europe.

The dominant preoccupations of the *permanent way engineers* are : modernisation of the track, organisation of maintenance works, and mechanisation of the work.

As regards *signalling*, mechanical signal boxes are being progressively replaced by electric signal boxes, and the block system and track circuits are being used more and more. The automatic block has been used in some cases. Centralised control of the points and signals is in operation in the St. Gothard tunnel. Mechanical distant signals are being replaced by light signals. The Signum system of automatic braking of trains is in general use on the electrified lines.

Lausanne-Sebeillon station is a good example of the complexity of the questions raised by the modification of a station and the huge expenditure involved in important alterations.

In his article : « The light weight rolling stock of the Federal Railways » Mr. GUIGNARD, who was one of the Reporters for the Lucerne Congress, gives details and very instructive data concerning the weight reduction not only of passenger stock but also of electric motor vehicles.

In view of the part played by electric traction in Switzerland, it can well be understood that in connection with *railway electrical installations*, the distribution of the traction current has been very carefully investigated. In the sphere of telecommunication, the Swiss Federal Railways have developped automatic telephony to such an extent that it is possible to telephone from any station on the system to any other, and the teleprinter has been installed in all stations where rolling stock has to be allocated.

The phrase « *timetables* » covers the whole organisation of the trains, i.e. the whole system of train communications. It is very curious to see an explanation of such concrete facts as that the desiderata formulated in this connection have led to modifications in the equipment and rolling stock, and how in their turn the fixed installations limit the possibilities of the timetable. All the resources of modern science are used to shorten the journey times : electric traction, light self-contained units, light weight stock, the best layout of the lines and track equipment. (In Renens Sta-

tion, the junction points can be run through at a speed of 90 km. [56 miles] per hour.)

The author of the last note ends by stating that the Swiss Federal Railways have doubtless made many improvements in the timetables during the last ten years. The same can be said for the other items dealt with, and this is why the « *Bulletin technique de la Suisse Romande* » has paid a fitting tribute to the Management of the Swiss Federal Railways.

E. M.

[385. (02]

The Railway Handbook 1947-1948, compiled under the direction of the Editor of the Railway Gazette. — A booklet ($5\,^1/_2 \times 8\,^1/_4$ in.) of 128 pages. — 1947. London : The Railway Publishing Company Ltd., 33, Tothill Street, Westminster, S. W. 1. (Price : 5 s.)

This is the fourteenth appearance of this annual handbook, the first number of which appeared in 1934. Its object is to give those interested in the railway a collection of very useful statistics and various information in a small sized volume at low cost.

The statistics are confined to the railways of Great Britain and Ireland, but the information given concerning the railways of the rest of the world make it possible to make useful comparisons. For example we might mention the mileage of the railways in the five parts of the world, the highest altitudes reached, the longest tunnels, the longest non-stop runs, the fastest runs, the longest straight section of track. As regards electric traction, the author has devoted a lot of space to this subject in view of the remarkable development of this method of traction.

The reader of this book will find that the most varied subjects are covered, great care being taken to stress the general principles and most striking features. The different kinds of locomotives, the stock used for traction and transport, compressed air and vacuum brakes, the make up of the permanent way and its maintenance, loading gauges, etc., are amongst the numerous questions dealt with in this way. A fairly extensive note deals with the present stage of development of signalling in England. The author gives a brief history of the use of liquid fuels on locomotives which is a matter of great topical interest. (The Ministry of Transport in August 1946 authorised the equipping of 1 217 locomotives in this way.)

To go back to the statistics for the English Railways, the development of the lines is given, the strength of the stock, the mileage run and the fuel consumed, for all the railways, for the years 1930 to 1946. Another table gives the general operating results for the years 1842 to 1894.

No doubt this is the last time that this review will appear in its present form for the four main line railways created by the 1921 Amalgamation. The law passed on the 6th April 1946 (Transport Act) has decreed the nationalisation of the whole of the British railways and part of the road transport undertakings. As regards the railways, the date of nationalisation was fixed for the 1st January 1948. The author gives a brief retrospect of the proposed reform, mentions the undertakings which will be affected, and gives some idea of the new organisation. About 60 railway undertakings extending to 52 000 miles will be nationalised. To these must be added 1 640 miles of canals and waterways. However many commercial vehicles now running under licence will not be included in nationalisation, so that the greater part of road transport will not come under the authority of the new British Transport Commission.

E. M.

[621 .13 (494)]

MOSER (Alfred), former engineer of the Swiss Federal Railways. — **Der Dampfbetrieb der Schweizerischen Eisenbahnen** *(Steam operation on the Swiss Federal Railways)*, 3rd edition, with a supplement for the years 1937-1947. — One volume ($9\frac{1}{2} \times 12\frac{1}{4}$ in.) of 426 pages, with 342 figures and numerous tables. — 1947, Basel : Verlag Birkhäuser, Elisabethenstrasse, 15. (Price : 30 Swiss fr., cloth bound.)

This book is the third edition of a work which has already appeared in 1923 and 1938. The second edition was reviewed in the December 1938 number of this *Bulletin*.

The present edition has been completed by a supplement giving the modifications made between 1937 and 1946 in the numbers of Swiss locomotives as well as a series of additional notes of a technical or historical nature.

There are 38 additional figures in this supplement, mostly photographic, to complete the valuable documentation previously collected.

The supplement has been published separately as a pamphlet of 32 pages for those who already have the previous edition (*).

The book is a very valuable document concerning the history of steam traction on the Swiss railways from their very beginning.

It covers not only the standard gauge railways, but also the narrow gauge lines and the rack railways.

The first chapter deals with the birth of the Swiss railways and the gradual development of the present system.

The author then reviews the way in which the stock of steam locomotives has been constituted, increased and modified during the course of the century which has elapsed since then, classifying them on technical bases. He mentions the improvements made during the course of time, covering each part in turn.

The book then gives detailed information on the types of locomotives which have been used on the Swiss lines, the name of the maker, the year, the number put into service, the year they were modified, as well as all technical details of their construction. This information is completed by many drawings and photographs.

From one end to the other the work shows the author's love of his work and the pasionate interest he feels in this vast subject. This makes it a particularly readable book. It is however above all a work of reference where all lovers of the steam locomotive and its history can find information unobtainable elsewhere.

J. V.

(*) The supplement (years 1937-1946) has been published separately for the Centenary of the Swiss Railways in 1947. — Publishers : Verlag Birkhäuser, Basel. It is a brochure (9×12 in.) of 32 pages with numerous illustrations. (Price : 8 Swiss fr.)

[38 (.494)]

Die Verkehrsmittel im Dienst der Wohn- und Siedlungspolitik. *(Means of transport to serve the country's domestic and social policy)*. Publication of the administrative course of the Higher School of Commerce of St. Gall. Volume 3. — One volume ($5\frac{3}{4} \times 8\frac{1}{4}$ in.) of 132 pages. — 1944, Einsiedeln/Zurich, Maison d'Editions Benziger & Co. A. G.

There is no need to insist upon the important part played by transport in the life of a nation. It forms the basis of a whole crowd of diverse activities which are nearly all vitally necessary : the transport of raw materials or finished products and foodstuffs, the journeys of workmen, businessmen, clerical staff,

and scholars, holiday journeys and tourist traffic, scientific, cultural or sports meetings.

To be effective transport must be adapted to the various objects for which it is required and the great multiplicity of the fields in which it plays an essential part makes this matter particularly difficult. The question is becoming more and more vital at the present time. In many countries, besides Switzerland, there has been a concentration of industrialism which means that crowds of manual and other workers are required at a few given points. Well organised and adequate transport alone can overcome overcrowding in the towns and industrial areas, and the uprooting of the country population. When the development of the large centres cannot be spread out, there is an acute housing problem.

In view of the considerable influence of transport on the live of a large number of citizens, the Higher School of Commerce of St. Gall has introduced two new subjects into its administrative courses, one dealing with the question of transport, and the other the policy of the Cantons and Communes. The reports covering the former have been published in the present volume by the School.

After an introduction defining the general scope of the new course, two reports are given on passenger fares and goods rates, followed by others dealing with the economic aspect of the train system, and with the administrative side of preparing timetables. All these reports, whilst giving very detailed information on the question are inspired by the general idea that the methods of transport should be adapted to the different needs of the population, bearing in mind the political-social object defined above.

The book is completed by two reports, one dealing with motor transport, and the other with tramways and omnibus lines depending thereon.

The ideas developed in these reports which are full of remarkable facts and statistical data should be studied by all those interested in the organisation of transport, whether as an operator, or official of the public authorities, or because of an interest in social questions.

E. M.

[**656** .1 (.44)]

Code de la circulation routière. (The Highway Code). — One volume ($5^{1}/_{4} \times 8^{1}/_{2}$ in.) of 400 pages and plates. — 1947, Paris, published by *Segar, France-Transports,* 61, boulevard Haussmann. (Price : 325 French fr.)

The Editor of the review « *France-Transports* » published in 1939 a book called « *Code of rail and road transport co-ordination* ». (See *Bulletin of the Railway Congress Association,* November 1939.) As its title indicates this volume dealt with administrative orders relating to the co-ordination of transport. The texts given and commented upon related to the economic and commercial aspects of the question. These were a step forward in the way of organisation.

The character of the present volume is completely different. It is concerned solely with road traffic and its regulation. This is a very obscure matter and all road users will owe the editor a debt of gratitude for having collected together the various orders and for giving a very valuable commentary on them.

It may be said that the reader will find in this book, apart from technique properly so called, all the information needed when using a vehicle. The main portion is devoted to the *traffic regula-*

tions. This is preceeded by all the *regulations concerning vehicles.* The third part is devoted to the very complicated question of *assurance,* and contains much valuable information and useful advice. The texts are arranged for easy reading, and the practical arrangement of the book makes it simple to find what one is looking for.

Doubtless the regulations may be revised in time, but it may be considered that the present code will remain the basis, as the solid principles from which the various regulations in force derive will not require any important alterations for a long time.

Though this book has no immediate connection with the operation of railways, it will be of interest to Companies who own road vehicles or operate road services.

It will also be extremely useful to the general public. Though the regulations under consideration apply to France, the book contains a great deal of information which is of documentary value and can be used as a basis of comparison.

E. M.

[**385** .63]

List of the frontier points open to international traffic in such traffic relations as are subjected to the International conventions concerning the transport of goods by rail (CIM). — Situation as on July 1st, 1947. — A brochure ($11\,^1/_2$" × $8\,^1/_4$") of 50 pages. — Published by the CENTRAL OFFICE FOR INTERNATIONAL TRANSPORT BY RAIL, Berne. (Price : 1 Swiss Franc.)

This list has been compiled in compliance with a wish expressed by a Railway conference held at Lugano from the 24th to the 26th April 1947. It enumerates, in so far as the necessary information was available, from the Railway Administrations concerned, the frontier points which were open to international traffic in such traffic relations as were subjected to a regulation, on July 1st, 1947.

These traffic relations have been arranged in the French alphabetical order of the countries. An index « Relations de trafic » enumerates these relations in both directions. The list is in French but the foreword is written in French, English, German and Italian.

If need be, the list will be brought up to date by supplements which will eventually be inserted in the *Bulletin des Transports internationaux par chemins de fer,* published by the Central Office.

[**625** .15]

COUR-PALAIS (Neville-H.). — District engineer of the Bengal-Nagpur Railway, Member, Track Standards Committee. — **Railway Points and Crossings. Theory and Practice.** Second edition completely revised. — One volume ($5\,^1/_8$ × $7\,^1/_2$ in.) of 436 pages with 256 figures, 25 tables and 8 plates. — 1944, Calcutta, Thacker, Spink & Co. Ltd., 3, Esplanade East, and London, W. Thacker & Co., 34-40, Ludgate Hill. (Price : 12 Rp.)

Special track equipment is of the greatest interest to railway engineers. Upon its geometrical layout and construction depends the cost of maintenance and renewal, as well as the safety of the traffic, quite apart from the safety equipment properly so called, with which we are not concerned in this case. As is also well known an increase in the speed at which points can be run through involves the realisation of special conditions.

There is a considerable amount of technical literature devoted to this question. This makes it clear that the regulations and specifications adopted by the different railways may differ appreciably according to what aspect is considered to be the most important. Several reports prepared for discussion at the 13th Congress of the International Railway Congress Association (Paris, June 1937) dealt with the special arrangement of points run through at speed.

Without detracting from the value of existing works, the author points out with reason that there are none which will meet at one and the same time the requirements of the designer, the maker, the engineer and the permanent way inspector. According to the problem to be solved or the work to be carried out, they have to refer to several different sources.

The author's object in writing the present volume has been to give a complete report which will make reference to other works unnecessary. We think he has succeeded in his aim, as the whole subject is covered from theoretical data to the most diverse applications.

All the geometrical and trigonometrical principles which are indispensible for making abstract calculations and carrying out work on the site are given in two chapters.

Three chapters are devoted to the constitution and construction of points and crossings. The seventh chapter deals with the geometrical layout of crossings, and the next two chapters with the use of crossings, covering every possible case. Further applications are then studied : connections between parallel lines, connections between non-parallel lines, then crossings, and slip-points, double cross-overs, double track junctions, three-way switches and triangles. The information given on groups of parallel lines connected to an outer track will be much appreciated. The theory of junctions in the form of parabolic transitions is amongst other up-to-date characteristics of the book.

It is difficult to make a choice of the points that deserve special mention. In Chapter V there is a very detailed discussion on the layout of points, which may be straight, curved, or partially curved, and a table of the dimensions of elastic points built according to the latest British specifications (Revised British Standard Designs). Chapter IV gives the characteristics of crossings which may be run through at speed in England, France, Germany, Belgium and the United States of America.

In the appropriate places details are given about the site, the composition of steel used for rails and the sections of rails used, together with their mechanical properties.

The final pages give numerical tables which are all of practical use, together with typical layouts of crossings conforming to the Indian Railway Standard Designs.

Although the book has been written to suit the circumstances obtaining in India and certain British Dominions, its usefulness is not limited to these countries as the formulae and theories apply to all gauges of permanent way, and can be used no matter what units of measurement are adopted. There is no doubt but that both the theorist and practical engineer will find therein nearly all the information they require on this extensive subject which has been covered from every aspect.

E. M.